NATURE-STUDY AGRICULTURE

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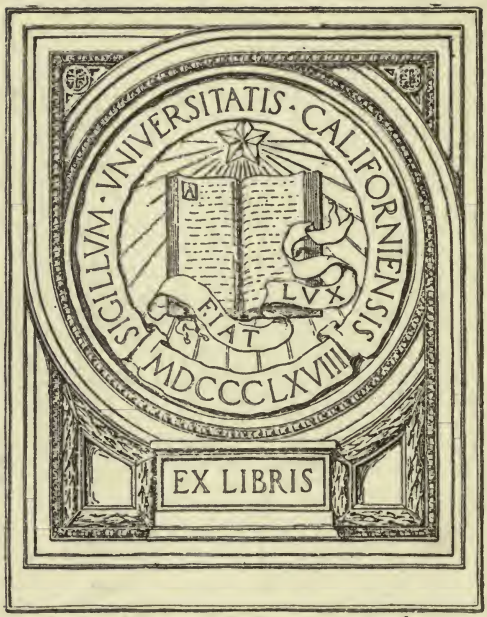
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A. T. Beals

FIG. 1. The ground floor of an education.

NEW-WORLD AGRICULTURE SERIES

NATURE-STUDY AGRICULTURE

A Textbook for Beginners

by

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ILLUSTRATED

with 266 engravings from photographs and drawings

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THE HOUSE OF APPLIED KNOWLEDGE

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In no pursuit is there more need for trained intelligence combined with industry than in agriculture; no subject offers better opportunity for combining the cultural and vocational elements in education. Taught in the spirit of nature study, agriculture brings the child into sympathetic relation with the fundamental realities of his world and at the same time gives instruction in the most basal of all vocations. Yet there have been lacking textbooks that would present the subject to elementary school classes from the nature-study point of view. Prompted by these considerations, the author and the publishers have prepared *Nature-Study Agriculture*, and it is their expectation that it will form a worthy addition to the list of Books that Apply the World's Knowledge to the World's Needs

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PREFACE

THE teaching of agriculture in grades below the high school has become well established in our schools, but opinions still differ as to the aims of the course and as to how the subject should be approached. The aim of an elementary course in agriculture is well stated in a late report of the Iowa State Teachers' Association: "to increase powers of appreciation, to promote general intelligence, to give a basis for the formation of educational ideals and the making of vocational choice, and to develop an appreciation of the possible applications of science to the useful arts." The most logical approach to the subject is through nature study, for the nature-study phase of agriculture, far more than the economic phases, deals with simple realities in the lives of boys and girls. Indeed, it is difficult if not impossible to dissociate the study of agriculture from the study of nature.

The manner of presentation is also the subject of most divergent opinions. There are those who contend that farming can be learned only by doing. This suggests the observation that a man might be employed on a farm, carrying out the instructions of another, for a lifetime, yet never come to understand the principles of farming. Similarly, a pupil might raise vegetables in a home-project garden, by simply following the directions on seed packages, and the benefit would be to his health rather than to his understanding. Yet, on the other hand, it is absurd even to think of teaching agriculture through textbook instruction alone. The reasonable

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procedure is to teach principles in the classroom, demonstrating them by simple experiments if possible, and at the same time to have each pupil, where circumstances permit, do some work in a school garden or on a home project. This practical work might well be conducted in such a way as to meet the requirements of home-project courses of study.

The subject of agriculture, especially as viewed from the nature-study angle, has so many ramifications that it would be unthinkable to give attention, in an elementary text, even to every pertinent matter. Yet a large measure of correlation with other subjects is inevitable, for agriculture "levies tribute upon all the sciences." In this book, subject matter has been included or excluded in accordance with the needs and interest of pupils as determined by the author during many years of experience as a teacher and supervisor of agriculture. The laying down of any rigid rules of procedure has been avoided, for the purpose has been to make *Nature-Study Agriculture* an ally to teacher and pupils anywhere. The instructor who uses this text may well see fit to omit parts of some chapters, or to supplement the matter in other chapters with material from the Farmers' Bulletins to which reference is made.

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NATURE-STUDY AGRICULTURE

CHAPTER ONE

THE NATURE OF PLANTS

Thou lift'st more stature than a mortal man's,
Yet ever piercest downward in the mold
And keepest hold
Upon the reverend and steadfast earth
That gave thee birth;
Yea, standest smiling in thy future grave,
Serene and brave,
With unremitting breath
Inhaling life from death.

SIDNEY LANIER, *Corn*

THERE is a pretty story of a Roman emperor who gave up his power and went to live in the province of his birth. When a friend wrote a letter urging him to become emperor again, he answered: "If you were but to come to Salona and see the vegetables that I raise in my own garden and with my own hands, you would talk to me no more about empire."

For us the choice is not between an empire and a farm; but many of us might choose between life in the city and life in the country. Attractive as city life may be, there is a pleasure in being face to face with nature, as in the country. We learn much on the farm that we could not learn in the city, and, like the Roman emperor, we find joy in securing the direct reward of our own labor.

Three divisions of the subject of agriculture

The farmer of all men needs to know many things. His business is far from simple. To manage a farm successfully it is necessary to understand the crop plants and

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FIG. 2. Grasses have fibrous roots. Extending in every direction, they form sod and keep the topsoil in many places from washing away.

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FIG. 3. The cabbage needs more support than does grass. Note the strong taproot and the many small roots branching from it.

how to raise them, the soil in which the crops are raised, and the animals to which they are fed. In a study of agriculture all three of these matters must be included. We shall begin our study with a consideration of the plant.

Different forms of roots

The parts of a plant: the roots. Roots are about as widespread and long underground as are the tops of plants above ground; and they differ in form as much as do the tops. (Exp. 1.)[1] Some plants, as grasses, have fibrous, threadlike roots (Fig. 2). Others, as trees, have roots that are large near the surface but branch and rebranch like limbs and twigs. Still others have

[1] See Experiments and Observations at end of chapter.

one central root, called a "taproot," more prominent than any of the branches, which goes straight down in search of water (Fig. 3). An example is to be seen in the long radish. This root growth may be compared to the top growth of such a tree as the tall, slender Italian cypress.

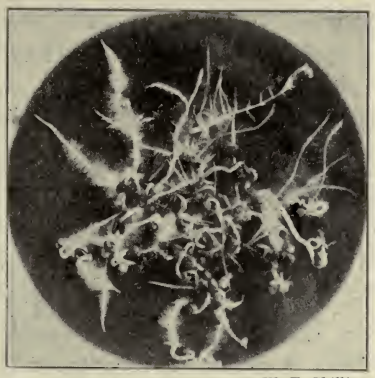

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FIG. 4. Root hairs on radish seedlings.

The uses of roots

The roots serve a double purpose. They furnish anchorage for the plant, and they absorb water and dissolved food materials. (Exp. 2.) Within the roots there are channels which lead up to the part above ground, but there are no openings in the roots to admit the soil moisture and its burden of dissolved food material. Evidently, then, this moisture must pass directly through the thin outer covering of the roots in order to enter these channels. The older and larger portions of the root are protected by an almost waterproof covering that resembles bark. But the outer layers of the newly started branches on the roots are soft and so let the water pass through. At the tip of each root there is a "root cap," a hard covering that shields the new and tender growth of the root as it thrusts its way among the soil particles. Just back of the root cap is the growing point.

How water and food materials enter

The root hairs

Near the growing point the root is covered with a multitude of small, tubular projections called "root hairs"

(Fig. 4), the outer walls of which are very thin. (Exp. 3.) It is into these delicate tubes that most of the water

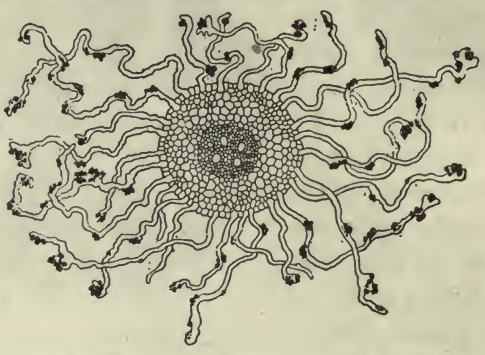


FIG. 5. Cross section of a small root, magnified, showing root hairs. (The black specks are soil particles.)

Their importance

and dissolved food material first finds its way. There are so many of these root hairs that their total surface is from five to ten times as great as the water-receiving surface of the roots themselves (Fig. 5). The root hairs

How they grow

die as the root grows longer. They never live more than a few days, and they never develop into roots. New root hairs grow out continually, just back of the growing point.

"Root pasturage"

The term "root pasturage" is sometimes applied to the work of the growing roots, as they make their way between soil particles and constantly send out new root hairs to absorb food materials and water from new soil

Why root hairs are hard to find

areas. We seldom see the root hairs, for although they are large enough to be easily visible, most of them are torn off when we pull up a plant even from loose ground. A sort of mucilage which they produce causes them to cling closely to the soil particles.

The effect of exposure on root hairs

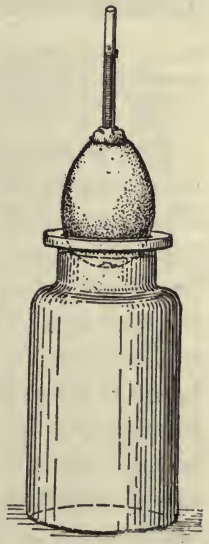
In transplanting, great care should be taken to protect the root hairs, for they shrivel and die almost at once if exposed to the air. Their home is in moist soil, and when taken out of the soil they are like fish out of water. Even an exposure of a few minutes will kill them. Since it is almost impossible to transplant a tree without destroying a large portion of the root hairs, a corresponding portion of the leafy growth should be removed. If this is not done, the few remaining water gatherers cannot keep the tree from wilting. (Exp. 4.) Trees are usually transplanted when they bear no leaves, because a tree will then need little water until it can develop new root hairs. As most of the feeding root hairs are at the ends of the roots, far out, often, from the base of the tree, it is there that we must apply water and fertilizer.

Why transplanted trees are trimmed

Where to apply water

The selection of plant-food material

Through some power that is not well understood, the roots select and absorb in larger quantities those substances that the plant most needs as food material; and this same power prevents them from absorbing other substances in the soil water that are not useful. Thus, although common salt may be more abundant in some particular soil water than potash is, the amount of salt absorbed will be small in comparison with the amount of the much more needed potash that is taken in.



U. S. D. A.

FIG. 6. Experiment to show osmosis.

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FIG. 7. Transpiration. These cans of earth were prepared in the same manner and were balanced; but the one with the growing crop (alfalfa) became the lighter because of its greater loss of water.

Osmosis

The process by which water, bearing its dissolved food material from the soil, enters the roots may be illustrated in various ways. One way is to use an egg (Fig. 6) to represent the roots. (Exp. 5.) Without breaking the white membrane within, pick off some of the shell from the base of the egg and seal a small glass tube into a small opening made through shell and membrane at the point of the egg. (Tallow dropped from a burning candle is good sealing material.) If this egg is set in water, it will correspond to the roots standing in soil moisture. The water will enter through the egg membrane and push the contents of the shell up into the glass tube. In the same way, water containing dissolved plant-food material enters the roots and pushes

Root pressure

upward the sap that has entered before. The mixing of two liquids through a membrane which separates them is called "osmosis," and the pressure that produces it is called "osmotic pressure," or in plants "root pressure."

The rise of sap

The plant stem. The stem, or in trees the trunk, connects the water- and food-gathering roots with the food factories, the leaves. Up through the channels in the stem, and into the veins of the leaves, the crude sap travels, carrying the dissolved mineral matter taken from the soil by the roots.

Transpiration

The larger part of the water in the sap that enters the leaves evaporates from them. This giving off of water by a plant is called "transpiration" (Fig. 7). Sap is drawn up to the leaves to replace the water that is lost. If sap cannot be drawn up as fast as it is evaporated, the leaves wilt.

Material retained

As water is transpired, the mineral matter that the sap contained is left behind to be made into plant food. Some of the water does not evaporate but unites with other materials in the leaf for the manufacture of plant food.

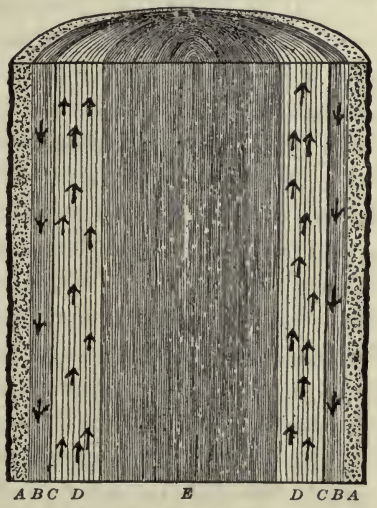

FIG. 8. How sap flows in a tree: *A*, outer bark; *B*, inner bark; *C*, growing layer (cambium); *D*, sapwood; *E*, heartwood.

The returning sap

The sap, after being changed in the leaves, streams away from them to all parts of the plant. It goes back, however, through a different set of channels from those through which it passed on its way up. Moreover, the returning sap is no longer crude; it is laden with sugar and other foods that have been manufactured in the leaves. It supplies nourishment, on its journey, to all parts of the plant, including the roots, and some of it is stored, in the form of starch, until it may be needed.

The difference between rising and descending sap

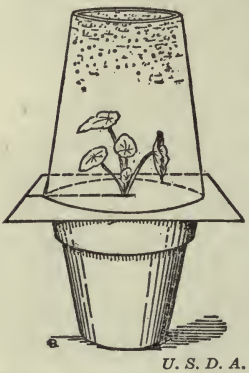

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FIG. 9. Droplets collect inside the glass, showing that plants give off moisture.

The course of sap through a tree

In an ordinary tree the sap runs up through the sapwood, which lies near the outer part of the trunk but still well below the bark. (Exp. 6.) The returning stream of sap comes down through the inner layer of the bark (Fig. 8). If a tree is girdled (cut all around) so deeply as to cut through the sapwood, it wilts and dies very quickly; but if it is girdled only deeply enough to cut through the bark, the tree may live for months. It will die eventually, however, for the roots cannot live long without the nourishing sap that is sent down from the leaves, since the crude sap which has not been to the leaves does not contain the food that the roots need.

Breathing pores in the leaves

The leaves. The surface of each leaf contains thousands of little openings, called "stomata" (Greek: mouths), into which oxygen and carbon dioxid from the air enter. It is through these openings, also, that most

of the moisture which has come up from the roots escapes. (Exp. 7.) It is a mistake to think that leaves absorb moisture from the air (Fig. 9).

The purpose of chlorophyll

The green coloring matter which forms in the leaves as soon as they come above ground is called "chlorophyll." It is with the aid of the chlorophyll that carbon dioxid from the air is combined with water in the leaves to form starch and sugar which nourish the plant. Animals as well as plants need carbon, but animals, having no chlorophyll, cannot take carbon from the air. They must get it from the plants. Plants take crude materials from earth, air, and water, and make them into substances that animals can use as food. They stand between us and the mineral kingdom, preparing from crude minerals food suitable for us.

How animals are dependent upon plants for their existence

Gases that come from plants

During the process of food manufacture, surplus oxygen is given off through the stomata. At night this action ceases, since light as well as chlorophyll is necessary for the manufacture of food. Then the plant gives off carbon dioxid instead of oxygen. A case is on record of a man being suffocated by this gas while sleeping at night in a poorly ventilated greenhouse.

How plants behave without chlorophyll

If the light is cut off from a green plant, it loses its chlorophyll, bleaches white, and eventually dies for lack of food. (Exp. 8.) An example of this is often seen in grass that has been covered with a board for a few days. If the board is taken away in time, the grass soon regains its natural color and resumes its growth. Plants that have no chlorophyll, like mushrooms and Indian pipe, lack the green color of ordinary plants. They have no power to use the carbon dioxid of the air in the

manufacture of their own food, and must therefore depend, as animals do, upon vegetable or animal matter for their food supply. For this reason they grow usually upon decaying organic matter, such as manure or logs.

Two functions of living things

Reproduction of the plant: the seed. So far we have considered only the vegetative parts of ordinary plants,—the organs that are essential to the life of the individual plant. But in the scheme of nature every kind of living thing has two chief functions: the one is to preserve its own life as long as possible; the other is to reproduce. Plants reproduce in different ways, and in Chapter Six we shall consider various methods by which they may be propagated. But most of the plants that we know, and almost all of those with which the farmer has to do, reproduce by means of seeds developed from flowers.

The parts of a flower

In Figure 10, the parts of a typical flower are shown. Only the ovules and the pollen are essential to reproduction. (Exp. 9.) The petals, forming the corolla, though the most beautiful part of the flower, can be picked off without seriously injuring the seed. The protecting calyx may likewise be removed. The ovary is merely the container of the ovules; the stigma and style form the

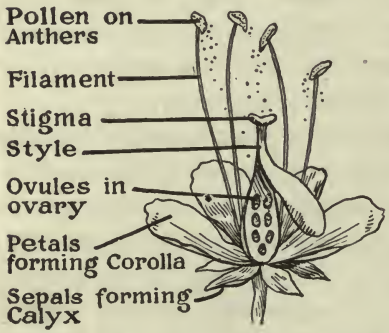

FIG. 10. The parts of a flower. (Anther and filament together constitute a stamen. Stigma, style, and ovary constitute the pistil.)

Why pollen and ovules are necessary

passageway through which the pollen can reach the ovules. Even the stamens and anthers are merely supports on which the pollen rests. We need to concern ourselves but little about these parts of the flower; but we must study the action of the ovules and the pollen, for they produce the new plant.

What a pollen grain does

When the flower opens, the pollen, which is a very fine powder, falls upon the stigma or is carried there by the wind or by insects. This is called "pollination." Immediately the pollen grains begin to grow, not upward, but down through the style. Like a delicate rootlet a pollen tube is sent downward until it touches the ovule at the bottom of the style.

We can see the pollen grain and also the ovule; but now, to make clear a wonderful process, we must speak of something which we cannot see without the aid of a powerful microscope; namely, the nucleus. The ovule has within it a nucleus; the pollen grain also contains a nucleus. When these nuclei meet, they grow together and the ovule becomes a seed. But for the coming of the pollen grain the ovule would shrivel and drop off, never becoming a seed or fruit (Fig. 11 and Exp. 10).

The parts of a seed

The seed consists of three principal parts: (1) the germ or embryo (a baby plant), (2) the food material needed by the growing germ, and (3) the seed coat.

How the seed germinates

When we plant the seed, it first absorbs moisture through the seed coat. (Exp. 11.) This starts the germ, which is already a tiny plant, to growing, and causes the starchy food material within the seed coat to begin to ferment. The fermentation prepares the food substance for use by the little plant as it grows. Even before the

leaves come above ground, the roots have begun to form and are searching in the soil for nourishment to take the

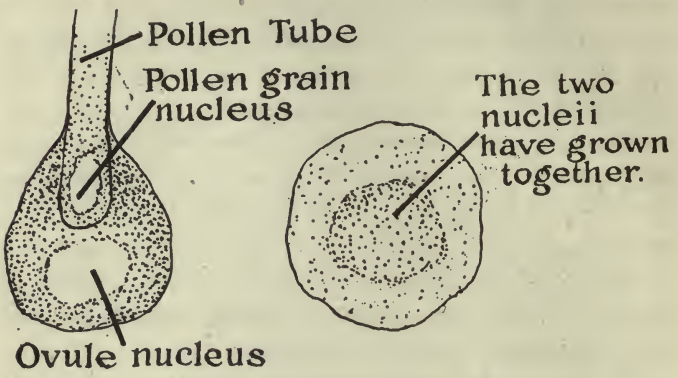

FIG. 11. How fertilization takes place.

place of that stored in the seed, for the scanty supply will soon be exhausted. (Exp. 12.) Rich soil is not necessary to start seeds — all they need at first is moisture, warmth, and air. (Exp. 13.)

Experiments and Observations

1. Make a collection of roots of various forms: fibrous; branching; with taproot; with store of nourishment; etc. Try to tell why each form of root is advantageous to a different kind of plant.

2. Cut off near the ground some vigorous plant and, by wrapping with adhesive tape, fasten a small glass tube to the cut stump. The rise of sap in the tube shows that water must enter the plant through the roots.

3. Place radish seeds between two pieces of wet blotting paper. Cover, and at one end let the blotter hang in water to keep them from becoming too dry. Root hairs will form in a few days (Fig. 4).

4. Transplant two small plants, cutting one back severely and leaving the other untrimmed. Watch their behavior.

5. Perform the experiment in osmosis described on page 6.

6. Place freshly cut stems bearing leaves and flowers in red ink, and set in the sunshine. After a few hours cut through the stems and leaves at various points to see where the sap flows.

7. Invert a glass jar over growing plants (Fig. 9). Notice the moisture that collects on the inside. (Best performed when the sun is shining.)

8. Cover green plants to keep light from them. After a few days note how the green color (chlorophyll) begins to fade.

9. Compare the various forms of stamens and ovules in as many different flowers as you can.

10. Just as a flower begins to open, cut off its stamens and tie a paper bag over it to protect from other pollen. See if the flower can set seed. (The dandelion would, but it is an exception.)

11. Plant a number of large seeds, such as beans or corn, in damp sand or sawdust. Dig up some each day and note the progress of germination.

12. Plant a few beans, and as soon as the plants come up, remove from some of them the two thick leaves with the bean hull on them. These leaves are really the larger portion of the original seed. Do not remove the little bud between them. After a week, note the growth of the different plants. Why are some of the plants stunted?

13. Plant seeds of the same kinds in soil, sand, and sawdust, and see if they germinate equally well. What is necessary for germination?

CHAPTER TWO

THE FOOD OF PLANTS

> Out of its little hill faithfully rise the potato's dark green leaves,
> Out of its little hill rises the yellow maize stalk.
>
> WALT WHITMAN

Learning about plant food materials through chemistry

To have an intelligent understanding of the soil and the sources of plant food, we must learn some of the things that chemists can tell us, for it is their business to study the composition of substances and the changes that take place in them. Chemists have found out that all things in the world are made up of only about eighty-five different elements.

Elements and compounds

An element is a substance that cannot be separated into any two or more things, for it is made of one thing only. Thus, hydrogen is an element but water is not, for water is made of two things, hydrogen and oxygen. (Exp. 1.) Iron, also, is an element, for it is made of only one thing, iron. Iron rust is composed of iron and oxygen. (Exp. 2.) It is a compound. A compound is a substance made of two or more elements united. Thus, water is a compound, and nearly all other substances, as stones, soil, fertilizers, wood, food, and even our own bodies, are made up of compounds.

Elements that any plant must have

Plant food materials; sources of supply. There are only ten elements that all ordinary farm plants must have in order to make leaves, stems, roots, seeds, and everything that the plant produces. These are as follows: potassium, calcium, iron, and magnesium; nitrogen, phosphorus, sulfur, and carbon; hydrogen

and oxygen.[1] Potassium, nitrogen, and phosphorus are the elements most likely to be deficient in any soil, and therefore they are the ones most needed as fertilizers (Fig. 12).

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FIG. 12. A pupils' collection of samples of the necessary plant-food elements.

How both earth and air furnish food materials

The plant takes all of its carbon and some of its oxygen from the air. All the rest of its essential food materials, including water, it takes through its roots from the ground. (Exp. 3.) In Figure 13 each of the side roots is shown absorbing one of the food materials, and the taproot, collecting water. Of course, every root absorbs all of these, but the picture is made in this way to aid the memory. The other essential food material, carbon, is shown coming to the leaf from the air.[2]

Water a food material and a carrier of food

However necessary the food elements from the soil may be to a plant, water is still more necessary, for mineral matter cannot be absorbed, except in solution. It must be dissolved in water before it can be drawn through the thin membranes of the root hairs. Not only does water carry food materials from the ground

[1] The first four substances named are metals; the second four are non-metals; and the last two are the elements of which water is composed.

[2] The water, carbon dioxid, and minerals that a plant uses are not foods. They are the raw materials from which the plant *manufactures* the foods that it needs.

into the plant and up to the leaves, but the two elements, hydrogen and oxygen, of which water is composed, are necessary in building up the woody fiber and other materials of which the plant is made. (Exp. 4.) Consequently, water may be considered a food material as well as a carrier of food.

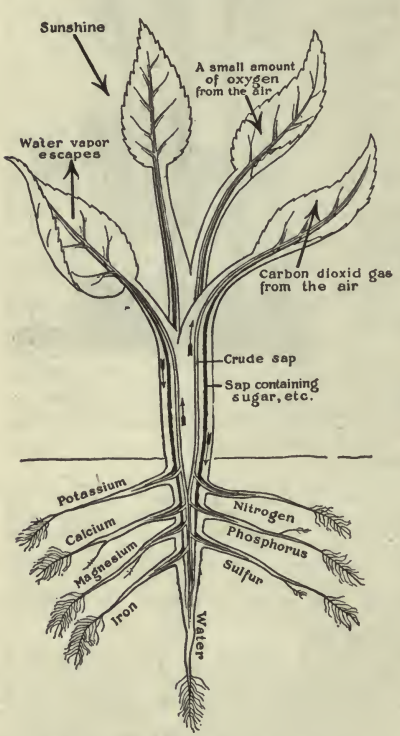

FIG. 13. Diagram to show how a plant supplies its needs from soil and air through roots and leaves. The arrows indicate the course of the sap within the plant.

What air does for plants

People seldom stop to think of what use the air may be to crops. Yet since less than half of the plant stands embedded in soil, and since the upper portion is continually bathed in air, it is only reasonable to suppose that air is of some service. In one respect it is more important than soil. It supplies the plant with far more nourishment than the soil does.

The gases that chiefly make up the air

Air is a mixture of several gases. The three most important gases in dry air are *oxygen*, *nitrogen*, and *carbon dioxid*. About one fifth of dry air is oxygen.

Nearly all of the other four fifths is nitrogen. A very small part is carbon dioxid. (Exp. 5.) All air contains some water, and this, also, is in an invisible gaseous form called *water vapor*. (Exp. 6.)

The process of breathing

Oxygen. In some respects oxygen is the most important of the gases that compose the air. It is the breath of life for animals and man. When we inhale air, oxygen is absorbed from it into the blood passing through the lungs. The oxygen of the air combines chemically with the impurities of the blood, slow combustion takes place, and carbon dioxid is formed all through the body. This gas is collected in the lungs and is breathed out as we exhale. If for any reason the lungs do not get a sufficient amount of oxygen, or if breathing ceases for even a few minutes, the system is rapidly poisoned, and death results. Plenty of air burns up the poisons that would otherwise accumulate in the blood. (Exp. 7.)

The effect of lack of air upon plants

Plant life, also, depends on oxygen (Fig. 14 and Exp. 8). The leaves absorb it, and the roots will not do well unless plenty of air fills the spaces among the soil particles. We know that a plant would not be suffocated by the exclusion of air for a few minutes, as an animal would be; but if a plant is unable to obtain oxygen for

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FIG. 14. There is air enough in either of these bottles for a few seeds, but not enough for many.

several days or weeks, it dies as surely as does an animal that is deprived of air. (Exp. 9.) Though plants absorb oxygen over their entire surfaces, they obtain the greater part of their supply through the leaves and roots. Sometimes, in a city or village, the leaves of a beautiful, healthy-appearing shade tree suddenly begin to wither and the tree dies. This is usually caused by gas escaping from the mains. The gas fills the air spaces in the soil, drives out the soil air, and the tree is suffocated.

What plants secure from carbon dioxid

Carbon dioxid. Though oxygen is essential, it is not required in nearly such quantity for the manufacture of foods as is carbon dioxid. (Exp. 10.) Carbon dioxid gas is the material from which plants secure the carbon that enters into the making of carbohydrates (starch, sugar, woody fiber, etc.). Carbon dioxid is also essential in the manufacture of the proteins and oils found in plants. Proteins and oils are for the most part formed within the seeds, as protein in beans, and oil in cottonseed, linseed, and olives. (Carbon dioxid is often spoken of as " carbonic acid gas," and the chemists abbreviate the name by writing it CO_2, the characters indicating that the gas is composed of one part carbon and two parts oxygen.)

Why motion of the air is necessary

There is so little carbon dioxid that in ten thousand parts of air only about three parts consist of this gas. Nevertheless, plants feed upon it so hungrily that they succeed in absorbing immense quantities of it. If the air were perfectly still, plants could not get sufficient carbon dioxid. For example, a three-hundred-bushel crop of potatoes on an acre uses as much of this gas as

there is in the air for about a mile in height above the acre. We can see why so much carbon dioxid must be taken in by plants when we realize that charcoal, which is the part that turns black when any plant substance is partially burned, consists almost purely of carbon. This carbon, of course, represents the carbon dioxid that the plant drew from the air through the stomata, the little openings in the leaves.

How much carbon dioxid a crop requires

Carbon dioxid, so necessary to plant life, is interesting also because of the many uses to which it is put. In the manufacture of soda water and all other carbonated waters, it is dissolved in the liquid under pressure. When the pressure is removed by drawing a cork or turning a faucet, the gas bubbles up, causing the effervescence. This same gas is sometimes used in the manufacture of ice. It is easily compressed to liquid form, and when the liquefied gas evaporates and expands, it draws heat away from the water, and so freezes it. (Exp. 11.) Bread is made to rise by carbon dioxid. The gas is generated all through the dough by the baking powder or yeast, and the bread is kept expanded until it is baked so that it cannot " fall " when the gas escapes.

Common uses of carbon dioxid

The plant life of the world daily uses thousands of tons of carbon-dioxid gas, and if this did not get back into the air the supply would soon be exhausted and nothing could grow. There are three ways in which the gas is set free from the plant substance in which it has been imprisoned. Plants either decay, are burned up, or are eaten. When they decay the carbon changes slowly to carbon dioxid gas, and goes back into the air.

How carbon dioxid is lost from the air

How it is restored

When they burn the change is more rapid, but here again the carbon forms carbon dioxid, and goes into the air with the smoke. When plants are eaten, the animals that eat them breathe out the carbon dioxid.

Experiments and Observations

1. Hold a cold flatiron in a flame. The moisture (a compound) that condenses on it is made by the uniting of hydrogen from the fuel with oxygen from the air.

2. With a knife or file scratch through the rust on a piece of old iron. Why is the rust only on the surface?

3. Into nine small bottles (Fig. 12) put materials to represent the ten elements that are essential plant foods, as follows: (1) Wood ashes (containing potassium), (2) lime or plaster (containing calcium), (3) iron, (4) a little flash-light powder (magnesium), (5) saltpeter or air (containing nitrogen), (6) matches (a compound of phosphorus), (7) sulfur, (8) charcoal (carbon), (9) water (hydrogen and oxygen).

4. Put a piece of perfectly dry wood into a test tube and heat it over an alcohol flame. The water seen collecting in the tube is made by the breaking down, in the wood, of compounds that contain hydrogen and oxygen.

5. Fill a glass with limewater and let it stand exposed to the air for several days. The crust that forms on the surface of the water results from the CO_2 gas of the air uniting with the lime in the water, making a thin layer of limestone.

6. That air contains water vapor is shown by the fact that moisture from the air will condense on a pitcher of ice water.

7. Into a Mason fruit jar put about two teaspoonfuls of sodium peroxid (from a drug store). Pour water upon it and cover the jar loosely. The jar will soon fill with oxygen. If a stick with a glowing ember at the end is inserted in the jar, the ember will immediately burst into flame.

8. To show that seeds will not grow without air, put a few wheat grains into a large bottle and half fill a similar bottle with

the grains. Add moisture, and cork the bottles. Why are the results different? (Fig. 14.)

9. Plant seeds in the same way in two cans of earth. Keep one can swamped with water, and let the other can drain through holes in the bottom so that the earth remains only moist. Explain any difference in the growth of the seeds.

10. Into a jar put a spoonful of soda, and pour a little vinegar or other acid on it. The gas that is formed is carbon dioxid. It will put out a match or a candle. To prove that the gas is heavy, pour some of it from the jar into a cup. A burning match put into the cup will go out.

11. Put a little gasoline or ether on the hand. Its rapid evaporation cools the skin. The far more rapid evaporation of liquid carbon dioxid would freeze the skin.

CHAPTER THREE

THE SOIL AND SOIL WATER

The first farmer was the first man, and all historic nobility rests on possession and use of land.

RALPH WALDO EMERSON

The importance of the soil

THE soil gives anchorage to plants, and from it they draw their entire supply of water and a large part of their food. To the farmer a study of the soil is quite as important as is a study of the plants themselves. He should know something about the way in which soil was formed, of what elements it is composed, its relation to water, and how its condition can be modified the better to meet the needs of the plants that he wishes to grow.

What the soil is

Soil, from the agricultural point of view, is the surface material of the earth that is suitable for plants to grow in. The greater part of it is composed of finely divided mineral matter which was formed by the crumbling and wearing away of rocks. (Exp. 1.) The depth of the soil may be only a few inches or it may be many feet (Fig. 15), but if we dig deep enough anywhere we come to the solid rock of the earth's crust. (Exp. 2.) This bedrock is what builders are after when they dig deep to lay the foundations for a heavy building. It covers the whole earth.

Bedrock

Soil-forming agencies. When we consider that soil was made chiefly from the rocky crust of the earth, sometimes even from volcanic lava, we are impressed with the idea that the processes of soil formation must have been very slow. We have now to study some of

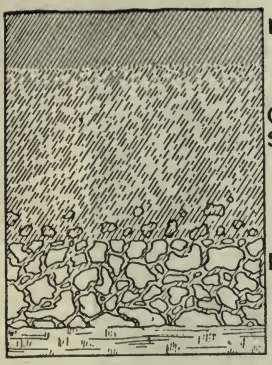

FIG. 15. The soil and the material below it.

the forces of Nature that slowly but steadily worked through the ages to produce the soil and to distribute it as we find it today (Fig. 16).

Chemical action

Probably the most important of the soil-forming processes is chemical action. We are all familiar with the rusting of iron. This is chemical action. If exposed to the weather, the brightly polished metal surface soon loses its luster and becomes coated with rust. Rust is not iron; it is a compound of iron and oxygen, as we saw in Chapter Two. And if nothing is done to protect iron from the weather, the process of rusting will go on until the iron is entirely consumed. In a similar way stones that are on or near the surface of the ground are acted upon by the weather so that they gradually crumble and change into new substances. (Exp. 3.) An example of this is to be had in the slow change of the rock feldspar into clay.

Soil formation and the rusting of iron compared

Changes of temperature

The effect of uneven expansion is illustrated when we break a piece of glassware by pouring hot water into it. The surface in contact with the hot water expands more than the rest of the surface, and the strain breaks the glass. Stones are often made up of several kinds of minerals, and as the temperature changes from

FIG. 16. Chemical action, changes in temperature, vegetation, and the action of the stream are all at work in forming soil in this Rocky Mountain cañon.

The breaking effect of expansion and contraction

night to day and from summer to winter, the uneven expansion and contraction of the different mineral particles tends to break the stones. Nature's process was imitated, we are told, when some of the roads were constructed in the Yosemite Valley: fires were built upon the obsidian rock or "volcanic glass" that was to be removed; then cold water was thrown upon the heated surface, cracking it.

Ice

Water, too, freezing in the pores and cracks of rocks, breaks them as it would break a pitcher. This is because water expands about one eleventh of its volume when it freezes.

Root growth

The roots of trees and of smaller vegetation as well help to split rocks that are already decomposing. The acids produced by growing roots help to dissolve rock particles, and thus aid in soil formation.

The formation of soil by streams

In the bed of almost any stream are to be seen smooth, rounded pebbles and boulders. These have come many miles from among the hills where the stream has its source. They were originally rough, angular fragments of rock, but they lost their corners by being jostled about and rolled over in the sandy bed of the stream. Figure 17 shows fragments of brick, glass, stone, and wood, that were worn smooth by this process. Not only were tiny fragments broken from the pebbles in the making, but the pebbles in turn wore the stream bed, gouging it out deeper and deeper. Thus the bits of stone acted as tools, grinding the rocky crust of the earth into soil.

Distribution of soil: the action of water. Running water has helped in the distribution of soil, as well as in its making. Steep mountains and hillsides often are almost barren of soil, not because there never was any there, but because it has continually been carried into the valleys below, by the water from rains and by streams. This accounts for the great depth of valley soil.

Why soil is deep in valleys

In some parts of our country, long ago, great glaciers hundreds of feet thick slowly slid over the ground.

W. T. Skilling

FIG. 17. Water-worn pebbles. Brick and glass above; stone and wood below.

The glaciers; what they did

These ice sheets were hundreds of miles in extent, covering a large part of what is now the United States and Canada. Much of the soil of our country owes its formation, or at least its distribution, to these glaciers. They acted like mammoth plows, scooping out deep channels in some places, and piling up great ridges of earth and rock in other places. Their action may be compared to that of a carpenter's gouge, for at the bottom of these moving masses were fastened stones which cut their way through the underlying earth, leaving marks still plainly visible. The geologist Dana estimates that the region south of Hudson Bay, where the ice sheet began to form, must originally have been from three to five thousand feet higher than it is at

present. From this great watershed the ice sheet moved slowly but irresistibly down into what is now the United States. The Middle West and the North owe much of their fertility and depth of soil to the excellent work done by this great ice mill. The grist it ground was rock, but the soil that resulted has produced the grist for many a flour mill which at present rumbles in that country.

Where the glaciers came from

Constituents of the soil. The mineral particles of the soil are classified in accordance with their fineness, as gravel, sand, silt, and clay (Fig. 18). All four come from the same source, rock, and they differ from one another only in the size of the particles composing them. If twenty-five grains of the coarsest sand are laid side by side, they reach an inch. Anything coarser than that is called gravel. It would require five hundred grains of the finest sand to extend one inch. Silt grains are so small that anywhere from five hundred to five thousand would be needed to reach an inch. Any soil in which the grains are smaller than this is clay. (Exp. 4 and Exp. 5.) In ordinary garden soil there are about a hundred billion grains to each ounce. Besides the mineral matter, gravel, sand, silt, and clay, there is present in all soils a small quantity of partially decayed organic matter, chiefly of vegetable origin. This is

The size of soil grains

Humus

Fig. 18. Comparative sizes of soil grains: 1, medium sand; 2, fine sand; 3, very fine sand; 4, silt; 5, fine silt; 6, clay. (All enlarged about 100 times.)

called "humus." Most soils contain a mixture of the five different kinds of particles. (Exp. 6.)

An imaginary view of the soil

The following illustration may help us to understand the nature of the soil. "Let us in imagination suppose a cubic inch of ordinary garden soil to be enlarged to a cubic mile — a magnification which no microscope would be able to give. Then we should see it composed mainly of a mass of rocks varying from several feet in diameter to the size of a pea and smaller.

"Each stone would be seen to be covered with a film of water, and some of the smaller spaces would be full of water. Larger spaces would contain air.

"Scattered throughout the rock mass we should see quantities of water-soaked decaying vegetation, like rotting logs in a mass of rock and gravel. Winding in and out among the stones and penetrating the spongy water-soaked humus is a network of plant roots, pushing aside the stones as they grow longer, and absorbing the water which fills the small spaces and with which the decaying matter, the humus, is saturated." [1]

Clay, sand, and loam

Soil textures. Like cloth, a particular soil may be said to be either of coarse or fine texture. Pure clay has a texture too fine to allow the easy circulation of air and moisture, and it is too sticky to work. Pure sand is of so coarse a texture that water drains out of it too easily, leaving it dry, and plants find little nutriment in it. A soil that has sufficient clay to bind the particles together somewhat and sufficient sand and humus to keep it from being too dense and sticky is called "loam." Loams are said to be sandy, or clayey,

[1] W. J. Spillman.

depending on the relative proportions of sand and clay. The texture of some soils can be improved by adding clay, of others by adding sand, and of still others by adding silt. Humus also greatly modifies the texture; it improves both sandy and clayey soils. The texture of all soils is greatly improved by tillage, if the cultivation is done when the ground is neither too wet nor too dry.

How texture may be improved

A "heavy" soil is one containing so much clay that it is sticky and hard to work. Sandy soils are called "light" because they are easy to work. By weight, sand is heavier than clay, a cubic foot of sandy soil weighing about a hundred pounds, while the same amount of clayey soil weighs about seventy-five pounds. Clay weighs less than sand, not because of being made of any lighter material, but because the total air space in dry clay is greater than the air space in sand. About half of the volume of clay soil is made up of pores filled with air.

Heavy and light soils

Heavy soils are usually richer and more moist than light soils, for they have more water-holding capacity and do not allow the humus to escape so readily as do light, sandy soils.

Their relative merits

Subsoil. The surface of the ground to the depth of six or eight inches (about as deep as the plow goes) has a darker color and contains more humus and other plant food than is found below this depth. If the plow is made to go deeper, it brings up sticky material that has not been exposed to the weather and is therefore not so well suited to growing plants. (Exp. 7.) This under layer of poorer soil is called "subsoil." Deep

The difference between topsoil and subsoil

plowing is to be recommended; but the plow should be allowed to go only a little deeper each year, so that not enough subsoil will be brought to the surface at once to injure the crop. The subsoil when exposed to the air gradually becomes good soil.

Why dry regions have no subsoil

In arid regions there is usually little difference in the soil for several feet down, for there is little clay and the soil, being dry, admits air. The West has, as a rule, no subsoil within reach of the plow. Sometimes soil that is taken from a deep excavation in a dry region is spread upon the surface, where it will support good crops even during the first season.

Soil water. The presence of water in the soil is one of the most important factors with which the farmer has to deal. As rain falls, it is absorbed by the soil; but different soils absorb different amounts (Fig. 19). By "annual rainfall" is meant the depth to which the ground in a particular locality would be covered in a year if none of the rain water ran off or soaked in or evaporated. (Exp. 8.) By adding the numbers representing annual rainfall for a series of years and dividing the sum by the number of years, we obtain what is called the "average annual rainfall." A sandy soil absorbs the rainfall more readily than does a clay soil; but clay can hold considerably more water than sand can. (Exp. 9.) The more humus any soil contains, the greater the quantity of water it can hold, and therefore the longer it will keep moist in dry weather. Sandy soil with little humus dries out very quickly. We shall now see why these soils act so differently.

Rainfall

Abilities of soils to absorb and hold water.

If a small stone is immersed in water and then lifted

W. T. Skilling

FIG. 19. Measuring the water-holding power of different soils.

How water is held in the soil

into the air, it will be covered with a film of water so thick that a few drops quickly run to the lower side and drop off (Fig. 20). The remaining water is so firmly held that the force of gravity is not strong enough to pull it loose from the rock. Now if the rock is allowed to dry in the sunshine until no more moisture is visible, there still clings to it a thin, invisible film of water. This last trace of water can be removed only by heating the rock to several degrees above the boiling point of water.

Free water and capillary water

Since the soil is composed mainly of small rock particles, each one of these particles behaves toward water just as the rock does. If soil is very wet, a certain amount of moisture drains down from one particle to another by the force of its own weight. This is called "free water." As the stone that has been wet holds

W. T. Skilling

FIG. 20. Free water and capillary water on a stone. Invisible water covers the top of the stone.

enough water to keep it moist, so the soil particles hold moisture which clings to their surfaces and fills the small spaces between them. This is called " capillary water," and the force that holds the water is called " capillary force." This force is named from the Latin word " capilla," meaning a hair, because it acts best in very narrow spaces. (Exp. 10.) Capillary force not only makes a film of water cling to the particles, but it draws the water up toward the drier surface of the ground. It is capillarity that draws oil up in a wick, and that causes water to rise in a very slender glass tube when we dip one end of the tube in water (Fig. 21). Capillarity, too, helps the sap to rise in the stems or trunks of plants.

W. T. Skilling

FIG. 21. Capillary action under different conditions.

Examples of capillarity

If a dry stone is partly immersed in water, the moisture will be seen to creep up a little way above the water level. (Exps. 11, 12, 13.) If a brick is set on end in a shallow pan of water, the water will in time draw to the top. Because the brick is porous, water can go up through the many capillary spaces within it much better than it can rise on the outside of a stone. Similarly, the small spaces in fine-grained soil like clay draw up and hold considerable water, and the larger spaces in coarse-grained soil like sand remain empty. So sand will not hold nearly so much water as clay.

What happens to water in clay and in sand

How humus holds water

A most important water-holding constituent of the soil is humus. This partly decayed matter not only holds water on its surface and in the small spaces be-

tween particles as the mineral elements of the soil do, but the water enters its very substance and saturates it like a sponge. Great quantities of water are held in this way if humus is abundant, and such water is easily given up to plants. Keeping the ground well stored with humus is, then, one of the most important of all good farm practices.

Where alkali comes from

Alkali and other soils. In all soils there is a continual weathering or decomposition of the soil grains, and soluble substances (one of which is common salt) are always being formed. Where the annual rainfall is large, these substances are washed out, conducted to streams and rivers, and carried to the sea. (That is why the sea is salt.) In those regions where the annual rainfall is small, as in parts of the West and the Southwest, the salts that form are left in the ground. When abundant, they are spoken of as "alkali" and the soil is called "alkali soil." In some places there is so much alkali that crops will not grow at all.

The cause of sour soil; the remedy

In the Central and Eastern states, sour soil is often met with. Sourness is due to acids that accumulate in the soil when it lacks lime. Lime neutralizes the acid as soda neutralizes the acid of sour milk used in cooking. So adding lime is the remedy for a sour soil. In some sections where the heavy rainfall has dissolved the natural lime and washed it out of the ground, liming will sometimes double the crop.

Color of soil

A black or very dark soil is universally regarded as a good soil, and it usually is such, the dark color being due to an abundant supply of humus. A light-gray soil indicates a deficiency in humus.

Temperature; effect of water

The temperature of the soil plays a very important part in the growing of crops. A light, dry soil warms up earlier in the spring than heavy, wet soil does. A soil that contains too much water is always cold for two reasons. It takes about five times as much heat to warm water as it does to warm dry soil (Exp. 15), and evaporation has a cooling effect, as we saw in Chapter Two. If a field is sloping so as to be well drained and the surface is kept loose and dry, the soil will be the warmer.

Experiments and Observations

1. Examine a little garden soil with a hand lens, or preferably with a microscope.

2. Dig a hole through the soil to bedrock if you can, or examine the soil at the side of a road cut. Can you distinguish soil and subsoil?

3. Collect decomposed rock that has been softened or at least stained by the action of the weather. Compare with an old break in iron.

4. Make several sieves about six inches square, with the sides of wood and the bottoms of gauze wire. Let the different meshes vary in diameter from the smallest mesh obtainable to one about a quarter of an inch in diameter. After crushing all lumps in about a quart of dry garden soil, sift it thoroughly, using each sieve in succession, beginning with the coarsest. Put the different siftings into separate glasses. Examine the samples carefully with the naked eye and with a lens.

5. Put a handful of soil into a tall glass jar of water. Stir thoroughly, and then watch the sorting action of water as settling takes place.

6. Collect in labeled bottles as many kinds of soil as possible. Note on each label whether or not vegetable growth seemed good in the locality from which the particular soil was taken.

7. Plant seeds in two pots, the first one filled with earth from the surface of the ground, and the other filled with earth taken from a depth greater than the plow ever reaches. Explain the results.

8. Set out a vessel with straight sides and measure the first rainfall. If there is snow, melt it before measuring.

9. To find how much water different kinds of soil are able to hold, proceed as follows: Wrap a string around several times near the bottom of a large bottle. Wet the string with kerosene, and after setting it on fire turn the bottle slowly till the fire goes out. Then put the bottle into water, and, if necessary, tap it with a hammer. It will break at the heated line, because of the strain due to the sudden cooling and contraction. Tie cloth over the mouth of the bottle and fill with dry sand. Fill several other such bottles with clay, loam, silt, etc. (Fig. 19). Find how much water each will hold without any draining through into a glass below. (Tin cans with holes punched in the bottoms will do instead of bottles.)

10. Put several glass tubes of different bores in a cup of water. Notice that the smaller the tube the higher the water is drawn by capillary force (Fig. 21).

11. Set a brick in shallow water and watch the capillary rise of the water (Fig. 21).

12. Lay two pieces of glass together (Fig. 21). Separate them on one side by putting a match between them. Dip one end of the glasses in water and observe that near the side where they touch the water is drawn higher than on the other side.

13. Set two glasses side by side, one full of water, the other empty. Connect the two by a lampwick (Fig. 21).

14. Set a pan of water and a pan of sand in the hot sun or near a stove. Which warms first?

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"Soil Fertility." Farmers' Bulletin 257.

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CHAPTER FOUR

SOIL FERTILITY AND ITS PRESERVATION

. . . If vain our toil,
We ought to blame the culture, not the soil.
ALEXANDER POPE

Worn-out farms

"A RICH soil makes a prosperous people." This is a very true saying, but it is not easy to keep a soil rich. There are many farms, especially in the eastern part of the United States, which once produced abundant crops, but which are now practically deserted because the fertility of their soils has become so low that the crops which can be raised are too poor to be profitable. Such farms are called "worn-out farms." In the Middle West, where the land has been brought under cultivation more recently, the soil is still rich and the crops are abundant; but these farms will also become worn out in time, unless proper methods of farming are employed (Fig. 22).

What the early settlers found

The fertility of wild land. For perhaps thousands of years before the coming of white settlers, luxuriant crops of wild prairie grass grew each year upon the plains of the Middle West, the soil probably becoming better, not poorer. What grass was not eaten by the buffaloes and antelopes was swept away by prairie fires after it became dry. When settlers first began to break sod, they found the soil black with richness. Whenever sufficient rain fell, abundant crops were secured. Before many years, however, farmers began to find their crops falling off and the land requiring fertilizers.

The effect of cropping

How could this land produce a natural crop for centuries without loss of fertility, while it showed the effect

FIG. 22. Hillside land that once was farmed. The topsoil is rapidly being carried away by rains.

of artificial cropping in a few years? An answer to this question may suggest a mode of farming more in keeping with the ways of Nature, which will not deplete the soil.

How we know that farm lands may be kept fruitful

If it were universally true that a long-used field became valueless, the prospect before us would be discouraging. But there are regions which under careful management have been producing good yields for many centuries. Indeed, some of the worn-out farms of the East are now, with modern scientific treatment, being made profitable again.

Three reasons can be assigned for the continued fertility of the Western prairies. First, the sod, formed by a close mesh of grass roots, served as a sponge to hold

How wild grass improved the soil on the plains

the water, and it prevented heavy rains from washing the nourishment from the soil. Second, as the roots decayed to make room for new ones, an abundance of humus was formed. (Exp. 1.) It is this humus that gives the characteristic dark color to prairie soil. Third, the grass, most of which was burned away each year, was not altogether lost, for the mineral food material that it had taken for growth was returned to the soil in the form of ashes.

Leaching

The loss of fertility in cultivated soil. Cultivated soil is more exposed to the action of rain than is land that is covered with sod. The more soluble substances in cultivated soil go into solution and are carried away. This process is called "leaching." If we should mix a pound of sugar or salt with the surface soil on a very small area, a few heavy rains would be sufficient to remove it almost entirely. A pound of marble dust or other insoluble substance would, on the contrary, remain for years. Certain plant foods, as compounds containing nitrogen, are as soluble as salt and sugar, and for that reason they leach out of the soil very readily, especially when no crop is growing to absorb and hold them.

What water removes

To find out what element of the soil's strength and how much of it is being wasted, it is necessary to collect samples of the drainage water and evaporate it completely. Although this water may be perfectly clear and colorless before evaporation, some solid material will remain. (Exp. 2.) This residue may be examined chemically to see of what it is composed. By examining the water of the Mississippi it has been found

that that river carries sediment and dissolved mineral matter enough into the Gulf of Mexico every year to make a block of earth a mile square and about three hundred feet high, if it could all be collected in one place.

The loss of humus; how avoided

The sod of the prairies is an ideal place for the formation of humus. But when the prairies are cultivated, the sod is destroyed; and if manure or other humus-making material is not added, the humus will gradually be used up, thus reducing the soil fertility. An excellent practice is to raise a crop of clover or timothy hay every few years, thus letting the land form a sod and so regain, to some extent, the condition it had in its wild state.

An unavoidable loss

Cultivated fields suffer a loss of fertility that does not occur in wild lands, through the annual removal of crops. The most fertile lands become worn out by cropping unless vegetable matter and food materials are returned to them. In time the vegetable matter that new soil usually has in abundance disappears, and the supply of mineral food materials that the plants must have becomes almost exhausted. This loss cannot be entirely avoided, and it becomes necessary to add fertilizers. These will be specially considered in Chapter Twelve.

Soil products that need not be removed

Keeping up fertility. With a little care the farmer can return to his soil a large part of the annual crop. Straw is almost valueless as feed and is easily given back by plowing under. Leaves that fall about a tree or under a rosebush should be kept moist and be dug into the soil. They will give back what the plant drew from the ground in making them, and will, besides, greatly improve the physical condition of the soil by increasing its humus.

U. S. D. A.

FIG. 23. Plowing under a cover crop to enrich the soil.

Cover crops

It is frequently advisable to raise a quick-growing crop for the purpose of plowing it under while it is still green (Figs. 23, 24, 25, and 26). This is called a "cover crop" or a "green manure crop." It is best not to plow too deep when turning the cover crop under, because the vegetable matter will not decay without air from the surface; about four or five inches is usually the right depth. Weeds may be treated in this way, as they are often rich in plant food. The best time for plowing them under is when they are in bloom, before they go to seed.

Making weeds useful

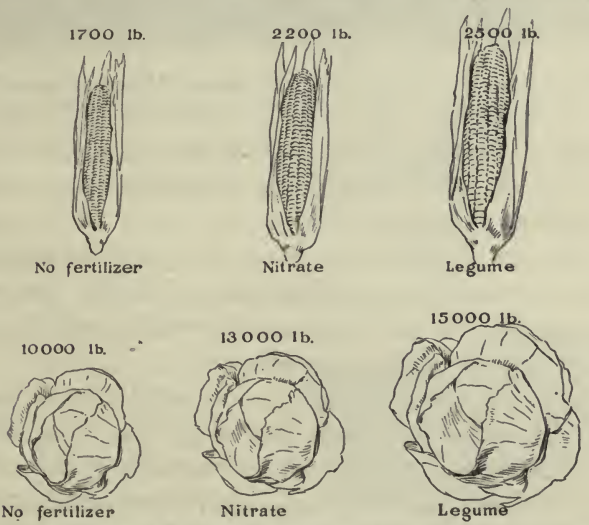
Why stock farming is good for the land

If, instead of selling all of his crops, the farmer would feed to livestock a part, at least, of what he raises, he could return to the soil, in stable manure, much of the plant-food material that is removed by crops.

Natural processes that enrich the soil. There are several ways in which Nature constantly adds to the soil some of the elements that it needs most. One of these elements is nitrogen. The atmosphere contains a small amount of ammonia, a compound that is rich in nitrogen; and every time it rains or snows, some of this ammonia is brought down to the earth and added to the soil. The weathering process that is continually going on in loose, cultivated soil is always making soluble new supplies of the food elements already in the ground. Wind and running water carry dust and earth from place to place, and these often add quite materially to the fertility of the soil. But the most interesting process

Rain and weathering

Wind and running water



FIGS. 24, 25, and 26. An experiment station in California got the above yields per acre from each of three similar plots. The first plot was not fertilized, the second was fertilized with nitrate of soda, and the third was fertilized by growing a legume crop (as clover) and plowing it under.

W. T. Skilling

FIG. 27. Peanut plant, a legume. After the flowers of the peanut are fertilized, their stems (peduncles) bend over and the pods develop in the ground.

The work of bacteria

of soil renewal is the one that depends upon the action of bacteria. The subject is so important that we need to consider it at some length.

The importance of nitrogen

Nitrogen is more likely than any other substance to be deficient, in soils, and, as plant growth is so utterly dependent upon this food, any means of supplying it or retaining it should not be neglected.

A question that puzzled the chemists

As soon as chemists began to investigate the materials of which soil is composed, they found that rocks, which by their disintegration produce soil, contain almost no nitrogen. An analysis of vegetable materials grown upon the soil, especially the grains and all seeds, revealed quantities of nitrogen in their composition. Where did the plants get it?

Why plants of the legume family can grow in poor soil

Early experiments seemed to show that the plants took no nitrogen from the air, — that all they got came from the humus (decaying vegetable matter) in the soil. But when plants of the legume family were tested, it was discovered that they would grow about as well in ground containing no nitrogen as in rich soil. (The legumes produce their seeds in pods like bean or pea pods.) In 1888, the scientist Helrigel found that upon the roots of such plants live multitudes of bacteria which enable the plant to secure its nitrogen from the air (Figs. 27 and 28). These "nitrogen-fixing bacteria" take the nitrogen gas from the air that is in the soil and unite it with oxygen and other elements. Then the plant can use it as food material. The process of making nitrogen unite with other elements is called "fixation of nitrogen."

Nitrogen-fixing bacteria

The nodules

U. S. D. A.

FIG. 28. A young red clover plant, another legume, showing nodules on roots.

If the student will pull up and examine the roots of clover, peas, beans, alfalfa, peanuts, or any other plant be-

W. T. Skilling

FIG. 29. Nodules on the roots of a peanut plant. Each nodule is the home of a colony of nitrogen-fixing bacteria.

longing to the legume family, he will find upon the roots little swellings, or "nodules," about as big as pinheads (Figs. 29 and 30). It is in the nodules that colonies of the nitrifying bacteria live, and these can be seen with the aid of a powerful microscope. The bacteria draw much of their own nourishment from the plant but do it no harm, and they give to the plant the nitrogen that it could not get alone. (Exp. 3.) Nitrogen thus taken from the air is added to the ground when the plant decays.

A partnership that is mutually helpful

How the farmer may help nature

Now comes the farmer's part in this process. If he plants vetches, clover, field peas, or some such leguminous crop, and plows it under, he may expect the suc

ceeding crop to be abundant, for this crop will use the nitrogen that has been gathered by the green manuring crop. (Exp. 4.)

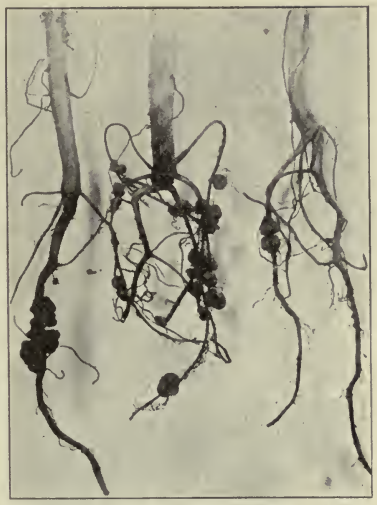


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FIG. 30. Bean roots, showing nodules.

How friendly bacteria may be added to the soil

It has been found that *inoculating* a field with the right kind of bacteria is sometimes of considerable benefit to a leguminous crop. This is done in two ways. Either (1) a few hundred pounds of the topsoil from a field where the same crop has been growing may be added to each acre of the new field; or (2) the seeds to be planted may be soaked in water to which a "pure culture" of the bacteria has been added (Fig. 31). When the seeds germinate, the bacteria will be near at hand to work upon the roots. Cultures of nitrogen-fixing bacteria for various leguminous crops are on the market, and they may also be secured from the Bureau of Plant Industry at Washington. It is not always necessary to inoculate a new field, for the needed bacteria may already be there living on wild clover or other legumes.

Encouraging other useful bacteria

There are other kinds of bacteria that make nitrogen available for crop plants. They do not live upon the roots of legumes but feed upon dead vegetable and ani-

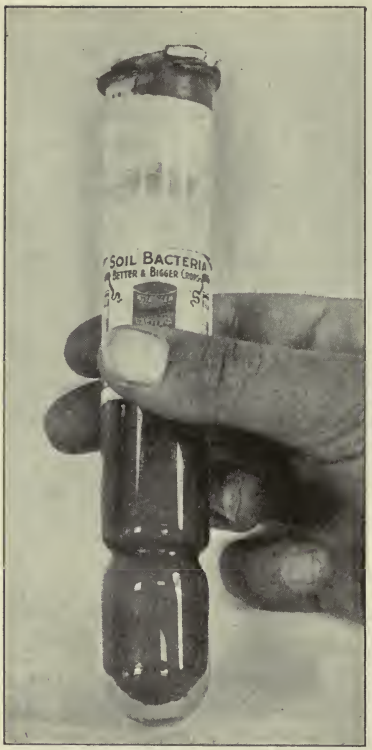

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FIG. 31. A pure culture of soil bacteria sufficient for an acre of clover.

mal matter in the soil. All that is necessary to get them working is to supply them with plenty of food. They are especially fond of manures, and they also like straw and stubble. Hence, if stalks, straw, and other refuse are plowed under instead of being burned, these bacteria will feed on them, and the amount of nitrogen in the soil will be increased.

Experiments and Observations

1. From a damp, shady place in a forest or from under bushes, collect soil which is rich in humus. Examine it for decaying leaves and similar matter. Plant some seeds in it and notice their rapid growth.

2. Evaporate a cup of clear well water to show that it contains earthy matter in solution.

3. See how many different plants you can find that have nodules on the roots. Do these plants have flowers similar to those of peas? Is their seed in pods like those of beans or peas?

4. Find out what kinds of legumes, if any, the farmers in your neighborhood plant to enrich their orchards and fields.

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CHAPTER FIVE

CULTIVATION AND DRAINAGE

Plow deep while sluggards sleep.
BENJAMIN FRANKLIN

ONE of Æsop's fables tells of a farmer who assured his sons, to whom he bequeathed his land, that in it there was buried treasure which they would find by digging. The treasures they found were the bountiful crops which their stirring of the soil produced. The soil, which is our country's richest treasure house, yields this nation annually about ten thousand million dollars in the value of crops and of animals fed upon crops. This amount, large as it is, could probably be doubled by more intelligent and thorough cultivation.

How plowing saves rainfall

The effects of cultivation. (1) *Cultivation allows rain to be absorbed.* It keeps the water from running off the surface of the soil and being lost. In dry regions the ground should be plowed or disked as soon as the crop is removed, so that water will be stored in the soil.

Effect on roots

(2) *It mellows the ground.* The stirring of the soil allows the roots to penetrate every part of it, and the more abundant the root system the better the plant is fed.

The value of a dust mulch

(3) *It prevents loss of water by evaporation.* Soil water is constantly being raised to the surface by capillarity and lost by evaporation. In dry weather this loss may be so serious as to injure the crop. One remedy is to keep the first two or three inches of the topsoil broken up to form a "dust mulch," or, in dry and windy regions,

a dirt mulch of fine clods. A mulch tends to prevent capillary water from passing through from the soil below, and thus, very largely, stops evaporation at the surface (Fig. 32 and Exp. 1). Whenever the mulch becomes packed, as it may after a rain, it should be restored to its former condition by proper cultivation (Fig. 33 and Exp. 2).

Keeping the mulch

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FIG. 32. The effect of a mulch. In a few seconds water rose from the glass vessel to the top of the loaf sugar, but it could not go up through the powdered sugar.

The need for air

(4) *It ventilates the soil.* The roots as well as the green portion of any plant must be supplied with oxygen, and they get it from the air that is found among soil particles. (Exp. 3.) If the surface of the earth is allowed to bake, air is excluded and the crop suffers. A plant, while growing rapidly, consumes about its own volume of oxygen daily, and a seed uses about a thousand times its volume of oxygen in the process of germination. The necessity for soil ventilation is very great, and the ventilating is done chiefly by cultivation.

Effect of air on helpful soil bacteria

In the last chapter we considered the bacteria that add to the store of available nitrogen in the soil. These helpful bacteria cannot work without plenty of soil air.

W. T. Skilling

FIG. 33. The earth that was allowed to pack and crust over lost water (became lighter) more rapidly than the earth that was stirred.

Cultivation, therefore, furnishes them with the air that they need.

Why weeds are harmful

(5) *It destroys weeds.* Weeds live on exactly the same kind of plant-food material that the crops require, and some use more food and water than do crop plants. Hence, every weed is a crop robber; and, as some weeds are hardier and more prolific than the crop plants, they may even crowd out a crop and take its place. Cultivation at the right time destroys the weeds and greatly benefits a crop (Figs. 35, 86, and 87).

The Egyptians used a crude wooden plow tipped with iron and drawn by men or oxen, to scratch up the surface of their fields (Fig. 36). With such methods a farmer could till but little land, and that little not very well. The plowshare made entirely of metal was not invented

until about one hundred years ago. The modern plow is better than the ancient plow because it not only loosens the soil but turns the earth upside down, covering any scattered trash or manure. It exposes the bottom of the " furrow slice " to the influence of sun and air.

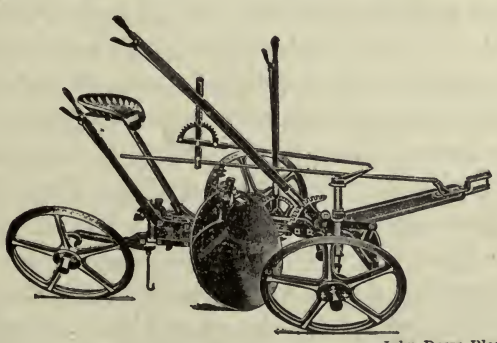
Advantages of the modern plow

Very deep plowing is usually beneficial, for it loosens a large quantity of soil in which the roots may search for nourishment and into which rain can readily be absorbed. However, the plow should not be run at the same depth every year, for its pressure and the trampling of the horse in the furrow will, in time, make a hard layer, called a " plow sole," at this level. This plow sole is a sort of artificial hardpan, through which the roots cannot easily grow. Plowing at a different depth each year will prevent the plow sole from forming. At a California experiment station the crop was nearly doubled in one year by plowing deep enough to break up the plow sole.

Deep plowing

Avoiding a plow sole

Plowing the ground when it is very wet injures it badly,



John Deere Plow Co.

FIG. 34. A disk plow is used to work soil which is so sticky that an ordinary plow will not turn it.

Bateman Manufacturing Co.

FIG. 35. Using a spring-tooth weeder to cultivate potatoes planted between rows of trees in an apple orchard. Such cultivation kills weeds and forms a dust mulch that preserves moisture.

Effect of plowing wet soil

especially if it is a heavy clay soil. (Exp. 4.) Bricks are made by working wet clay (puddling it) and then drying and baking it. A wet clay soil is puddled by the plow, and the sun dries the furrow slices into something resembling brick. If a handful of earth will not crumble easily upon being pressed, it is too wet to plow.

Harrowing

All the ground that is plowed should be harrowed the same day, while it is moist and crumbly. Clods are not easily broken after they become dry. But fall plowing should be left rough — not harrowed.

Dragging

A drag made of several heavy planks fastened together is sometimes drawn over the plowed field to level the surface and break the clods (Fig. 38).

Rolling

A roller may be used before the land is harrowed,

Metropolitan Museum of Art

FIG. 36. Egyptian agriculture. (Picture from an ancient tomb at Nakht, Egypt.)

in order to pack the loose soil somewhat against the wet subsoil and thus aid capillary action in bringing water up to the seeds or roots. Such a roller as that shown in Figure 39 is better than a solid one, for it leaves a dirt mulch on the surface.

The beginning of modern methods of cultivation

It is less than two hundred years since machinery began to be much employed in the cultivation of crops. Jethro Tull, an Englishman, is known as the father of the modern system of cultivation. While traveling in southern France he saw that the farmers were planting their crops in rows, and cultivating them with a kind of plow drawn by horses. Returning to England, he enthusiastically recommended the method, and published a book called *Horse-hoeing Husbandry*.

Instead of using horses to draw farm machinery,

Farming with tractors

many farmers are now using tractors, two forms of which, the type that runs on wheels and the " caterpillar "

Gale Manufacturing Co.

FIG. 37. A spike-tooth harrow.

or " track-layer " type, are coming into wide use (Fig. 40). The caterpillar type rests on a chain belt. Having a larger surface to press against, the weight of the engine does not bear so hard at any one point as it would if it were supported on wheels. The caterpillar engine is especially valuable for work on soft land. Either form of tractor will do more work than a team of horses, for it will go faster, pull harder, and work longer hours. A small tractor will do the work of at least four horses.

A comparison of tractors and horses

Use of tractor as a stationary engine

The tractor may be used as a stationary engine by connecting it with a belt to other machinery. In this way it can be made to operate a pump, a threshing machine, a silage cutter, or a circular saw.

Reclaiming swampy land

Drainage. Marshes and swamps cover considerable areas of the country. The water in them becomes stagnant and foul, making breeding places for mosquitoes; and though the soil is usually rich, it cannot be farmed because of the water. When properly drained, such land will produce good crops.

Damp lowland, as well as marsh land, sometimes needs drainage, for the free water in it comes so near to the

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FIG. 38. A home-made plank drag or clod crusher used in preparing the seed bed for barley.

U. S. D. A.

FIG. 39. A roller that leaves the surface loose.

Fig. 40. Plowing sod with a tractor.

surface that the roots are drowned. If we dig a hole a few feet or sometimes only a few inches deep in damp land, we may come to a place where water begins to seep in. (Exp. 5.) The upper surface of this free water which runs out of the soil if it gets a chance is called the "water table." The roots of most farm plants, excepting rice and cranberries, will not grow below the water table, because they cannot get enough air there. For this reason the water table should not be very near the surface of the ground. In sloping, well-drained land there is usually no free water and therefore no water table near the surface.

The water table

Artificial drainage, by lowering the water table, increases the depth to which roots can go and so makes available a larger supply of plant-food material. It helps to ventilate the soil and to make it warmer; it makes the soil looser and lighter and easier to work with farm implements; and it greatly increases the number of the beneficial soil bacteria. Even though no plant

How drainage affects the soil

food be added to the soil, the fertility of the field is greatly increased, and soil that would otherwise be too wet for farming is made productive.

Protection against drought

Drainage also protects crops in time of drought, a well-drained field being drier in wet weather and having more moisture available in dry weather than one that is not drained. The reason for this is that in an undrained field the roots develop in the thin upper layer of drier and ventilated soil. Later in the season the plants may even suffer from drought, for as drier weather comes on the water table is lowered and not enough moisture may be left in the surface soil to support the crop. But where there are drains the surplus water is carried away in the rainy season, while in dry weather the plants, being deeply rooted, do not suffer.

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FIG. 41. This flowerpot was filled with earth to which a small quantity of salt had been added. Water that was allowed to drain through carried with it much of the salt. Note that a crust of salt was left on the flowerpot when water seeped through the sides of the pot and evaporated. An alkali crust on the ground is formed in a similar manner.

Alkali

In some parts of the West where irrigation is practiced, drainage serves to carry away an excess of alkali (Fig. 41 and Exp. 6).

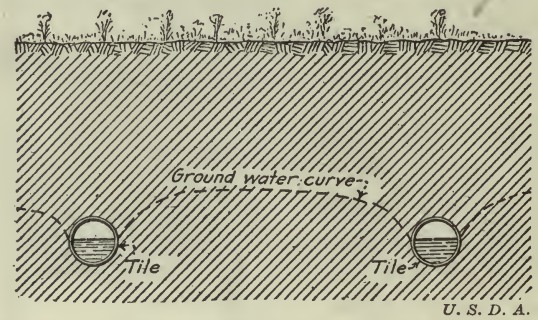

FIG. 42. Cross section of soil, showing tile in place. The soil is drained and roots can grow above the "ground-water curve."

Drainage by ditching and by tiling compared

Open ditches may be used to carry off surplus water, but they are very inconvenient and take space where crop plants might grow. Underground drains, on the contrary, leave the surface of the field as it was. They are made by laying short lengths of tile end to end several feet underground. The water gets in where the ends of the tiles are loosely joined to one another. The water table cannot stand much higher than the bottom of the drain (Fig. 42), for any free water will run into the drain and be carried away.

Experiments and Observations

1. Pulverize a little sugar with a table knife. Heap the powdered sugar upon a lump of loaf sugar and set the lump into a shallow dish of water. How far does the water go up? What does this experiment suggest as to the effect of a mulch? (Fig. 30.)

2. Set a cup on each pan of a pair of scales and put the same amounts of equally moist earth in each cup, making the scales balance. Then pack the dirt in one cup and loosen the surface of the dirt in the other. After a few days' absence, which cup has become the lighter through loss of water? Why has this cup lost the more water? What does this suggest as to the cultivation of a field? (Fig. 31.)

3. To show the presence of air in soil, drop a clod into water and notice the bubbles.

4. Wet two spots of clay soil. Immediately work one spot very thoroughly with a hoe. Let the other spot become nearly dry and hoe it. Compare the condition of the two spots a few days later.

5. Dig down in low ground to see if you can locate the water table.

6. Partly fill a flowerpot with earth mixed with a spoonful of salt, and set the flowerpot over a vessel that will catch the drainage. Pour water on the soil and evaporate the water that drains through. What became of some of the salt that was in the earth? How might a field be freed from alkali?

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"Management of Soil to Conserve Moisture." Farmers' Bulletin 266.
"Tile Drainage on the Farm." Farmers' Bulletin 524.

CHAPTER SIX

THE PROPAGATION AND CARE OF PLANTS

Jock, when ye hae naething else to do, ye may be sticking in a tree; it will be growing, Jock, when ye're sleeping.

SIR WALTER SCOTT

Making a right beginning

THE old saying, "Well begun is half done," is a good motto for any one undertaking to plant a garden, a lawn, an orchard, or a field. Mistakes made in the beginning are hard to correct afterwards. Some common mistakes are failure to prepare the ground well before planting, using seeds and plants of poor quality or poor variety, and careless planting.

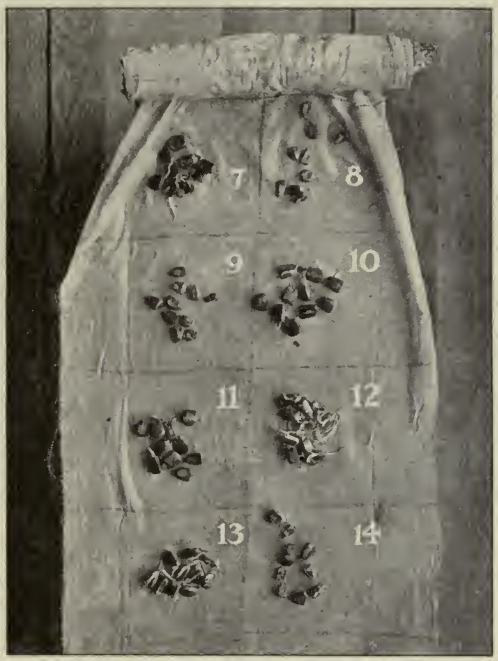
Five methods of multiplying plants

The principal methods of propagating (starting) plants are (1) planting seed, (2) planting cuttings (slips), (3) layering, (4) grafting and budding, and (5) planting bulbs. Whichever of these methods may be used, the most important thing is to start with seed or other material from the best possible parent plants. After that, the most necessary matter is properly to care for the plants while they are young. But no amount of care will make possible the raising of good plants if one starts with poor stock.

The selection of good parent stock

Why seeds need to be tested

Propagation by seeds. In Chapter One we noted that each seed has a hard outer coat. Within this outer coat is the young plant or embryo, together with a supply of food on which the new plant lives until its roots and leaves are well started. The process by which the seed becomes a young plant — that is, by which it sprouts — is called "germination." Some seeds will not ger-



U. S. D. A.

FIG. 43. The "rag doll" method of testing seed corn. The cloth, with the test grains in place, was rolled and tied, and it was kept thoroughly damp until the seeds germinated. The ten grains on each of the squares came from a separate ear that bore the number in the square. The ears numbered 8, 9, and 14 should not be planted.

minate at all; others germinate so feebly that the plant will either die or be weak and puny. Therefore seeds should be tested before they are planted (Fig. 43).

A simple test

A convenient method of testing seeds is to count out a certain number, as one hundred, spread them on one end of a flannel cloth that has been wrung out of water so as to be damp but not saturated, and lay the other

end of the cloth over to cover the seeds. Place the folded cloth in a plate and turn over it another plate to prevent too rapid evaporation. Set it in a warm place and examine daily to remove all seeds that have sprouted. If as many as ninety seeds out of one hundred germinate, the seed may be considered fairly good. (Exp. 1.)

Storing seeds

If seeds are properly selected and cared for at harvest, and if they are properly stored till planting time, there will be little trouble in getting them to germinate.

Keeping fruit seeds moist

Most seeds should be kept dry until planting time, but those of apples, pears, peaches, and cherries, which are inclosed in a juicy fruit, should not be allowed to become dry after being removed from the fruit. If they remain dry long, the embryo dies. Such seeds should either be planted immediately or be kept damp until time to plant. They may be mixed with damp sand, put in a bag, and kept in a place so cool that they will not germinate until planting time; or they may be layered in sand. To layer seeds, cover the bottom of a box with damp sand; lay a cloth over this, and place a layer of seeds on the cloth; cover the seeds with another cloth, and on this place a new layer of damp sand. Proceed in this manner until the box is filled with alternate layers of seed and sand. Keep the box in a cool place.

Why seed corn should be kept dry

Seed corn should be kept in a cool, dry place. If it is allowed to absorb moisture or is not thoroughly dried after gathering, the moisture will freeze in the kernel and kill the germ. When the kernels are very dry, there is little danger that they will be damaged by freezing.

A good way to store seed corn is to remove the husks

FIG. 44. Stringing ears of seed corn. *U. S. D. A.*

and string the ears, hanging them from rafters or from a wire; or they may be strung as shown in Figure 44 or stuck on spikes as in Figure 45. Another good way is to turn the husks back, braid them together in bunches, and then suspend the corn. The ears may also be laid in racks, but there they are likely to be attacked by rats and mice. Under no circumstances should the ears be allowed to touch each other. (Exp. 2.)

Ways of storing corn

Whether seeds are planted in the open field, the garden, or the greenhouse, the method of preparing the seed bed is the same in principle. The chief difference lies in the degree of care that it is possible to take. In all cases the seed bed should be (1) deep, (2) well drained, (3) mellow, (4) well packed below the surface, but (5) fairly loose on top, (6) free from clods, (7) as level as

The seed bed

Eight conditions to be desired

Preparation of seed bed

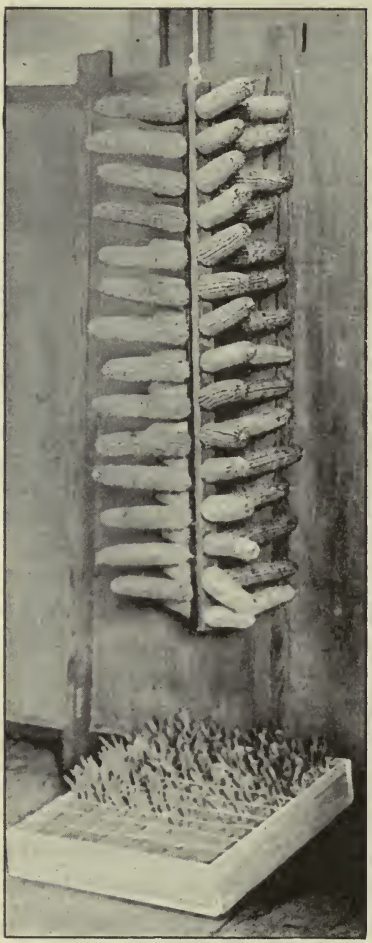


FIG. 45. Seed corn stuck on spikes. Notice the seed-test box below.

possible, and (8) composed of soil well supplied with plant food.

The process used in getting the seed bed into proper condition will depend upon its size. Deep plowing in the field, deep spading in the garden, and filling a box with fresh soil in the greenhouse will all accomplish the same purpose,—they will mellow the soil and admit air, giving the roots a chance to penetrate to a good depth. Clods should be broken up immediately, except after fall plowing, which is left rough over winter.

Garden soil

Proper richness of soil cannot always be had in large fields without great expense; but in a garden, where so much and such expensive seed is used and where so much labor is expended, it is false economy to save on fertilizer.

The right soil for seed boxes

A soil suitable for seed boxes ought to have sufficient sand and humus to keep it from forming a crust. One-third ordinary soil, one-third sand, and one-third leaf mold makes a good mixture.

Packing the soil

Packing the soil, as we have seen, is accomplished in the field by means of a roller or a subsurface packer. In the greenhouse a flat wooden block called a " float " is used to firm the earth in the seed boxes. The surface in both cases is afterwards made loose, — in the field by harrowing and in the greenhouse by sifting a layer of fine soil on top of the packed soil in the seed boxes. In the garden a rake is used in making the mulch.

Tools used

Depth of planting; a greenhouse rule

A rule often given for greenhouse planting is this, — that a seed should be covered with a layer of soil equal to its own thickness. Thus a coconut might be placed about seven inches underground, but such fine seeds as those of the begonia should have as little covering as possible. They are sometimes covered only with a damp cloth, which is removed when the seeds are sprouted.

Why small seeds must be near the surface

A small seed must be near the surface because the new plant cannot begin to draw nourishment from the air until it comes up into the light. If it has far to come, it may die of starvation before it reaches the surface. A large seed, having a greater store of nourishment, may send up a shoot through several inches of soil before the young plant needs to depend upon food of its own making.

Rules for field planting

In the field and garden, where the surface of the ground is very dry and moisture from below is relied upon to cause germination, the seeds must be put deep enough

for the capillary water to reach them. (Exp. 3.) In cool, wet weather, however, seeds need the surface warmth which the sunshine supplies, and they will rot if too deeply covered. The looser and drier the soil, the deeper the planting should be. The usual depths for planting are: clover and grass seeds $\frac{1}{2}$ to $1\frac{1}{2}$ inches; wheat, oats, etc., $1\frac{1}{2}$ to 3 inches; beans, 1 inch; peas and corn, 2 to 4 inches. The smaller depths above given are for heavy, moist soils; the greater depths are for light, dry soils.

Proper spacing; the danger of planting too thickly

Planting too thickly often accounts for poor results. If very close together, plants interfere with each other's growth and become weak and spindling, just as they do if they are crowded by weeds. If plants come up too thickly they should be thinned at once, before they begin to crowd each other. In doing this, keep in mind the size that the plant will have when full grown. Large seeds are seldom planted too thickly; but great care has to be used in planting small seed like that of turnips. One good way to handle such seed is to mix it with fine, dry sand or dust before planting. Another method often employed with cabbage, onion, and lettuce seed is to sow it thickly in boxes of earth and transplant before the plants are big enough to crowd each other. In China, where labor is cheap and land is scarce, this method is employed in raising rice.

Propagation by cuttings. A "cutting" or "slip" is a piece of a small branch or twig planted to take root. Even a leaf of some plants will take root and grow (Fig. 46). Most of our house plants, and roses, and such fruit plants as currants and grapes, are propagated by

cuttings. One advantage in propagating by cuttings is that growth is generally more rapid than from the seed. Another advantage in their use is that the plants produced will be like the parent plants, whereas seedlings are often very different, especially in fruits and flowers.

Advantages in the use of cuttings

W. T. Skilling

FIG. 46. A leaf cutting of begonia.

Most trees and shrubs and vines — plants of hard and woody fiber — grow best from cuttings made of wood that has had a year's growth. These are known as "hardwood cuttings" (Fig. 47). On the other hand, herbs such as verbenas, fuchsias, and petunias — soft and pulpy plants — grow best if the cuttings are made from the soft tips of growing branches. Such slips are called "softwood cuttings" (Fig. 48).

Two kinds of cuttings

A hardwood cutting should be long enough to include at least two nodes (the place from which a bud grows), — one to produce roots, and one for branches to grow from. The lower cut should be made just below a node, and the upper cut, if there is to be one, between two nodes. Softwood cuttings should be very short, including only one bud.

The preparation of cuttings

Where to cut

Preventing decay and wilting

Cuttings must be made with a very sharp knife. A clean cut heals over more easily than does a torn and

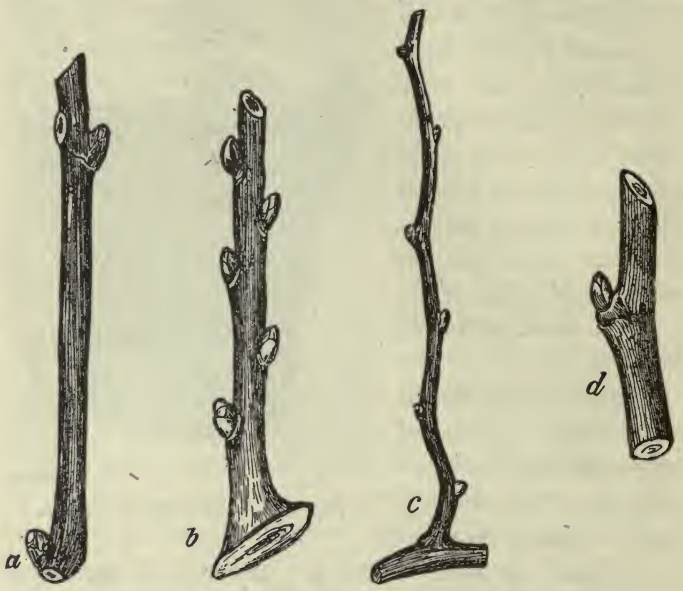


FIG. 47. Hardwood cuttings: *a*, simple cutting; *b*, heel cutting; *c*, mallet cutting; *d*, single-eye cutting.

slivered end; and unless the wound quickly becomes "callused" over with new growth, bacteria will soon enter and cause decay. All leaves that would be covered and a part of those that would be above ground should be removed. Covered leaves might start decay, and too many above ground would draw moisture from the cutting and dry it out too much. (Exp. 4.)

Planting cuttings; why sand is used

In the planting of cuttings it is necessary to keep in mind the need for air. It is especially desirable for the production of roots that plenty of air be present, and for

this reason cuttings should be started in coarse, damp sand (Fig. 49). No other nourishment than air and moisture is necessary for getting the roots started, and as sand admits air more freely than other soil does, it is better to use either that or a very sandy loam. Slips are often prevented from forming roots by being kept too wet. Even sand, if water-soaked, will not admit air; and there must be proper drainage or the cuttings will rot. (Exp. 5.)

The effect of too much water

About three fourths of the length of a cutting should be placed below the surface. The purpose in planting so deeply is to prevent drying out. A light-colored cloth screen laid loosely over a bed of slips helps to keep the tops moist. A glass jar is sometimes set over the plant to prevent loss of moisture.

The purpose in planting deeply

Some plants, such as the geranium and the Wandering Jew, grow so easily from cuttings that little care is necessary. But with most plants roots cannot be so easily induced to start, and if we would succeed well we should follow the best methods.

Cuttings are most easily removed from the sand bed as soon as they have callused over at the cut, but before roots have actually appeared. (After the cut has healed by being callused over, roots are quite certain

When to transplant

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FIG. 48. A softwood cutting. (Slip of coleus.)

FIG. 49. Starting cuttings of geranium. Geraniums are among the easiest plants to propagate in this way.

to develop.) Cuttings from roses often die if they are disturbed when the roots are young. So it is better to plant rose slips in the open ground with a shovelful of sand in each hole, leaving them for a year before transplanting. They will then be thoroughly rooted.

The advantage in layering

Layering. As a cutting must depend upon the nourishment within itself until it can produce roots, it must be protected very carefully from influences that would cause it either to dry out or rot. But if a twig can be left joined with the parent plant while it is forming roots, there is little danger of failure (Fig. 50). This can be done by bending the branch or vine down to the ground, covering a part of it in the moist earth, and letting it remain there until roots develop and a new plant is formed. This process is called "layering." Bushes and vines, as black raspberries and grapes, may be started in this way. (Exp. 6.)

In layering, as in preparing cuttings, the leaves and buds which would go underground should be removed. The covered portion of the stem must be fastened securely to prevent it from being moved by the wind. A shovelful of sand or leaf mold mixed with the earth at the point where the branch is buried will make it root more easily.

Methods of encouraging roots to start

A notch is sometimes cut at the point where it is desired to force out roots, as they develop more easily at a cut. A better method is to split the branch (Fig. 50, *a*) and put dirt into the opening. In ring layering (Fig. 50, *b*) advantage is taken of the fact that sap cannot run back toward the roots if a ring of bark is removed; that is, if the branch is girdled. Nourishment from the roots can flow past the girdle, for it travels within the stem. But the returning sap flows

Ring layering

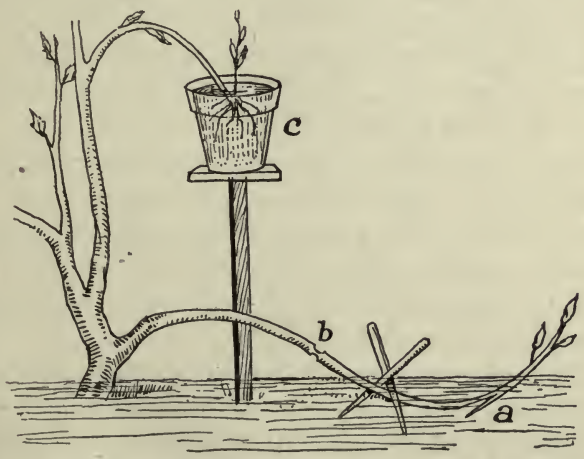

FIG. 50. Layering: *a*, stem split to start roots; *b*, ring of bark removed; *c*, "tip layering" in pot. Notice the crossed stakes which hold down the stem that has been laid underground.

in the inner layer of bark and so is checked at the girdle, concentrating nourishment at the point where roots are to be produced.

Layering in a box

If branches are too high to be layered in the ground, a box of earth in which to start the new plant may be supported as shown in Figure 50, *c*. Such a box or pot may also be used for branches at the ground; then, when roots form, the plant is already potted and is easier to remove.

Offsets; runners; rhizomes; suckers; division

Various methods of propagating. Bulbous plants such as tulips and hyacinths form new shoots on their roots which can be separated and replanted. These are called "offsets."

Plants like the strawberry have creeping branches which send roots down into the earth at intervals, thus starting new plants. Such branches are called "runners" or "stolons" (Fig. 51).

Rhizomes are underground runners. They are not roots, but are rootlike stems which send up shoots here and there, as in the iris.

Suckers are young plants that grow from the roots of the parent. They may be seen coming up around an elm tree. Some blackberries are propagated by transplanting suckers. Suckers from grafted trees are not good to transplant, for they will be like the seedling upon which the grafting was done.

Division is a good means of propagating some plants, particularly ferns. A plant is divided through the roots or rhizomes, and the parts are set out as separate plants.

Advantages in grafting

Grafting and budding. In grafting, a branch several inches long from one tree is inserted into another. If

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FIG. 51. A strawberry plant that was set out in the spring at Osage, Iowa, photographed in the middle of July. Note the runners in bloom.

a bud instead of a small branch is grafted into another tree or shrub, the process is called " budding " (Fig. 52). In either case the fruit produced on the branches growing out of the graft will be exactly the same as the fruit of the tree from which the graft was taken. In fact, the " scion," the new growth from the point at which the graft was made, is but a continuation of the original tree from which the scion was taken, not a new tree as is one raised from a seed. Seedling fruit may or may not be good, but we can know the quality of grafted fruit beforehand. This was noted as an advantage in the use of cuttings. But in grafting, a double advantage can be secured, since the root which is to support the tree may also be selected. Since this is so, nurserymen try to graft the best fruit-bearing branches upon

How scion and stock are selected

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FIG. 52. White roses budded on a red rose bush. All characters of the budded roses — as shape, size, and color — are the same as they would be if the roses were growing on their own bush.

varieties that have the hardiest roots. It must be remembered, however, that only closely related trees can be grafted — as peaches on plums or apricots, but not peaches on apples. The plant into which the scion is grafted is called the "stock."

Putting the growing layers in contact

The process of grafting is not very difficult, but budding is so much easier that it is more commonly practiced than grafting. (Exp. 7.)

In either grafting or budding, the most important thing is to see that the growing layer of the bud or graft is placed in contact with the growing layer of the stock. The growing portion of a tree is the layer that lies just under the bark. This is called the "cambium

layer." The method by which cambium layers of stock and scion are brought together is made clear in Figures 53, 54, and 55.

The tongue graft

The " tongue " or " whip " graft is very commonly used. Scion and stock must be of about equal size, the diameter of a lead pencil being about right, and cuts should be made as shown in Figure 53. In uniting the scion and stock, care must be taken to have the growing layers of the two stems in contact, at least on one side.

The saddle graft

In the " saddle graft " the stock is cut wedge-shaped; the scion is split, placed over the stock, and firmly pressed down. A saddle graft is easier to make than is a tongue graft, but it has rather less cut surface where growth may take place. (Exp. 8.)

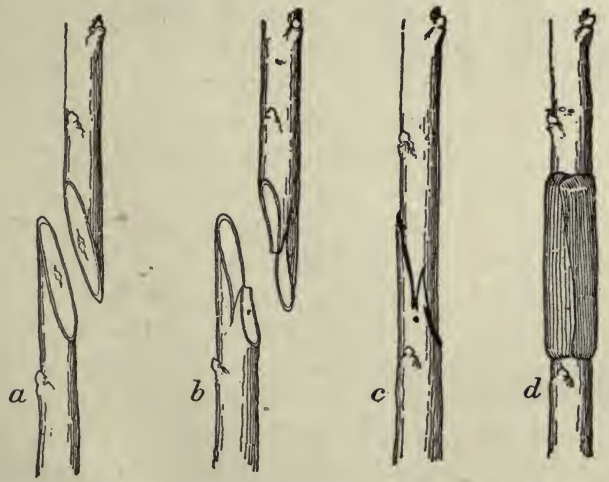
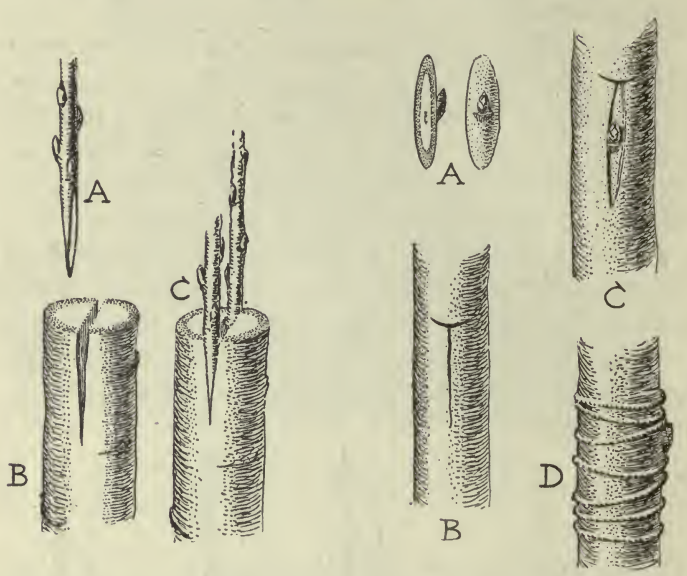


FIG. 53. The four steps in whip grafting: *a*, the first cuts; *b*, the cut surfaces extended to increase contact of cambium layers; *c*, scion and stock joined; *d*, the graft bound up.

"Working over" a tree

Grafting is usually done when the stock is small, one year old or less, but sometimes an old tree is "worked



FIGS. 54 and 55. Cleft grafting (left) and budding (right). In each figure, *A* is the scion and *B* the stock; *C* shows scion and stock joined.

over" or "top grafted," in order to make it bear more desirable fruit. In this operation "cleft grafting" is used. All the limbs are sawed off, the ends are split or sawed open, and a graft is wedged into the end of each limb. Sometimes two grafts are inserted (Fig. 54). Unless the graft is firmly wedged in place, it must be tied with raffia or soft cord. (Raffia is a fiber that comes from a kind of palm. It may be purchased at seed stores.) The binding material must be removed as soon as growth begins. When the limbs are taken

off, the tree should be protected from sun scald by a coat of whitewash. Often a few limbs are left until the next year to shade the tree.

Grafting wax

In all grafts, wax is spread over the place where the stems have been joined. This is done to keep out air and moisture. Where slender stems are grafted, they are generally bound together before the wax is applied. Good grafting wax can be made by melting together one pound of tallow, two pounds of rosin, and a pound of beeswax.

Budding

The most common method of budding is illustrated in Figures 55, 56, 57, and 58. It is known as "shield" or "T" budding. For this work buds should be selected from the middle part of the branch. Those at the tip are too young, and those far back are too old. They should be dormant (resting); that is, they should not have begun to unfold. A well-developed bud is chosen, and the edge of a sharp knife is placed crosswise half an inch above it. A cut is made downward through the bark till the knife comes out half an inch below the bud. With the point of the knife some of the wood is picked from the back of the bud. If there is a leaf at the bud, it should be cut off so as to leave the petiole for a handle. A T-shaped cut is made in the stock; the bark on each side of the vertical cut is rolled back, and the bud is inserted (Fig. 57).

Selection and removal of bud

Inserting bud in stock

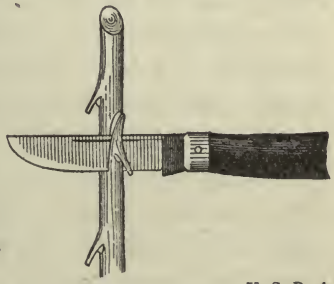


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FIG. 56. Cutting a bud.

A wet strip of raffia is

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FIG. 57. Budding seedling fruit trees; inserting a bud, and wrapping with raffia.

Binding it

used to bind the bud in place. Care should be taken to cover the cut entirely with the raffia so as to exclude air and prevent drying. Sometimes a little grafting wax is smeared over the cut, but this is usually not necessary. The raffia should be removed as soon as the bud shows signs of growth, which will usually be within a month or six weeks.

Any sprouts that may grow on the stock after budding should be removed. The bud will then grow more rapidly, as it will receive all the nourishment that the root system produces (Fig. 58).

The time for budding and grafting

Grafting is usually done in the spring when the sap begins to flow. June and July are considered good months for budding; but this may be done successfully at any time when there is sap enough to make the bark loosen easily. (Exp. 9.)

Caring for trees. A seedling fruit tree may be budded when it is about a year old. It is then left in the nursery until the bud has had a year to grow, when the tree may be higher than a man's head and have many branches. Upon removal to the orchard, it is at once pruned back (Figs. 59 and 60). The central stem is cut off (headed) about thirty inches above the ground; only four or five of the strongest limbs are left, and even these are usually much shortened. Every cut should be made just beyond a bud, so that no stubs will be left to

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FIG. 59. Peach trees pruned, ready to plant.

Pruning the young tree

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FIG. 58. When a bud has grown fast, the stock is generally cut away, just above the bud.

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FIG. 60. Peach tree six months after planting.

die. The manner of pruning a peach tree until it is ready to bear is shown in Figures 61, 62, and 63.

After a fruit tree is given the desired shape by the first few years of pruning, it needs little attention other than to be kept from growing so many branches as to crowd the fruit or keep out the sunlight (Fig. 63). Any dead branches should be trimmed out.

Protecting orchard trees from frost

There are a few weeks in early spring when fruit buds are liable to be injured by frost. Many orchardists have stoves ready to light on frosty nights. The temperature of an orchard may be raised several degrees by these outdoor fires (Fig. 65).

An orchard on low ground is in much greater danger of being injured by frost than is one on high ground (Fig. 66). Cold, like water, flows to the bottom of a valley. A sharp narrowing of the walls of a valley, or a grove of tall trees within it, will check the flow of air as water is checked by a dam. Such a place, where cold air cannot drain away, is badly chosen for an orchard. (Exp. 10.)

If a tree is injured by animals or disease or by being

Wickson's "California Fruits"

FIGS. 61 and 62. First year in orchard: Fig. 61 (left), branched yearling, and same tree cut back at planting; Fig. 62 (right), first summer's growth in the orchard, and first winter pruning (December). Compare Figures 59 and 60.

Wickson's "California Fruits"

FIG. 63. Second year in orchard: second summer's growth (September); second winter pruning (December).

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FIG. 64. Pruning tools: curved blade saw, hedge shears, and long- and short-handled lopping shears.

Tree surgery

broken by the wind, it may often be repaired so that it will recover from the injury. Figure 67 shows methods of "tree surgery," which may add many years to the life of a valuable tree.

Experiments and Observations

1. Test one hundred of each of several different kinds of seeds.

2. Before the first heavy frost, select several of the best ears of corn you can find and store them in one of the ways described in this chapter.

3. To test the proper depth of planting, plant in the garden a few seeds of each of several different crop plants: barely cover a few seeds of each variety; cover a few of each half an inch deep, a few of each an inch deep, then others two, three, four, five, and six inches.

4. See how many different kinds of plants you can make grow from cuttings, following the directions given in this chapter.

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FIG. 65. Oil heaters in use in an orchard.

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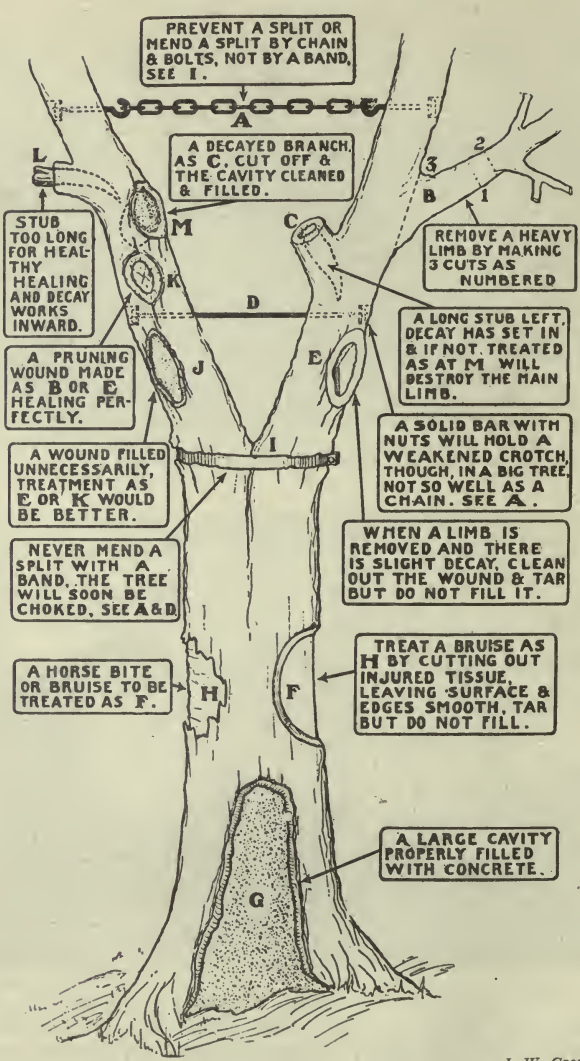
FIG. 66. One morning, at daybreak, the Fahrenheit thermometer registered 39 degrees above zero on top of this bridge, and there was, of course, no frost at that level; but in the valley below the thermometer registered 29 degrees, and there was a heavy frost.


PREVENT A SPLIT OR MEND A SPLIT BY CHAIN & BOLTS, NOT BY A BAND, SEE I.
A
A DECAYED BRANCH, AS C, CUT OFF & THE CAVITY CLEANED & FILLED.
L
M
C
K
D
J
E
I
H
F
G
B
1
2
3
STUB TOO LONG FOR HEALTHY HEALING AND DECAY WORKS INWARD.
A PRUNING WOUND MADE AS B OR E HEALING PERFECTLY.
A WOUND FILLED UNNECESSARILY, TREATMENT AS E OR K WOULD BE BETTER.
NEVER MEND A SPLIT WITH A BAND. THE TREE WILL SOON BE CHOKED. SEE A & D.
A HORSE BITE OR BRUISE TO BE TREATED AS F.
REMOVE A HEAVY LIMB BY MAKING 3 CUTS AS NUMBERED
A LONG STUB LEFT. DECAY HAS SET IN & IF NOT TREATED AS AT M WILL DESTROY THE MAIN LIMB.
A SOLID BAR WITH NUTS WILL HOLD A WEAKENED CROTCH, THOUGH, IN A BIG TREE, NOT SO WELL AS A CHAIN. SEE A.
WHEN A LIMB IS REMOVED AND THERE IS SLIGHT DECAY, CLEAN OUT THE WOUND & TAR BUT DO NOT FILL IT.
TREAT A BRUISE AS H BY CUTTING OUT INJURED TISSUE, LEAVING SURFACE & EDGES SMOOTH, TAR BUT DO NOT FILL.
A LARGE CAVITY PROPERLY FILLED WITH CONCRETE.

J. W. Gregg

FIG. 67. Methods of tree surgery.

5. Prove the need of underdrainage by planting seeds in two cans, only one of which has holes punched in the bottom. Keep both thoroughly watered.

6. Try to make vines take root by layering them.

7. Following the directions that have been given, see if you can successfully bud and graft rose bushes or young trees.

8. Start a little nursery at school or at home by planting peach pits in spring. The next spring, bud the seedlings.

9. Make a list of all the ways by which plants are multiplied, as mentioned in this chapter. See if you can find some example of each in your neighborhood.

References

"School Exercises in Plant Production." Farmers' Bulletin 408.
"Pruning." Farmers' Bulletin 181.

CHAPTER SEVEN

THE IMPROVEMENT OF CROP PLANTS

Whoever makes two blades of grass grow on a spot of ground where only one grew before deserves well of mankind.

JONATHAN SWIFT

THE term "plant improvement" does not refer to the improvement that is made by giving the crops better care and richer soil. It refers to the development of better varieties which, with equally good care and soil, will yield more profitable crops than the old varieties.

Improved plants; the apple

The fine mellow apples which we enjoy today are known to be descended from very different apples that were cultivated by the Romans. Those earlier apples grew in clusters instead of singly, and they were very small. Pliny, the Roman naturalist, describes them as being sour enough to take the edge off a knife. Both

The potato; the tomato

the potato and the tomato as found growing in America when Europeans came were much inferior to those we now have. The wild types of both of these still grow in South America, and they are scarcely fit for human food. Figure 68 shows the wild tomato from which the cultivated varieties have been derived. It grows under almost desert conditions and abundantly bears fruit of the size of a marble.

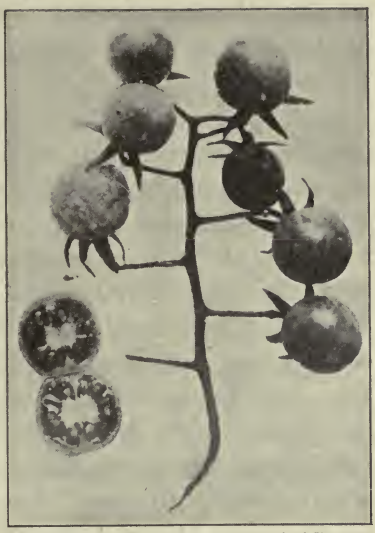
Methods

Seed selection and plant breeding. It is not only interesting but it is important for us to know the methods by which improvements have been made in crop plants, for if we know what has been done we shall be better able to do our share in carrying the work of improvement still farther. Two principal methods have been

employed. They are seed selection and plant breeding.

Plant improvement by selection

The earliest accurate record we have of crops being improved by selection of seed from the best plants dates back about one hundred years. At that time a botanist was visiting a farmer who lived on the island of Jersey in the English Channel. The botanist examined the farmer's growing wheat and found that many slightly different varieties were growing together in the same field. The farmer thought that he had only one kind of wheat, but the botanist was able to gather heads of twenty-three types from one field. Some of these were better than others, and it occurred to the farmer that if he could get rid of the poorer types and raise only the best, instead of a mixture, his profits would be greater. After the departure of his visitor, the farmer planted the twenty-three heads of wheat in separate plots. When these were grown, he saved the seed from the plots that seemed better than the others and replanted it; and so he continued to do year after year. He soon had enough seed of the selected varieties for



Journal of Heredity

FIG. 68. The seedy and acrid little fruits of the wild tomato (about one fourth natural size).

How a farmer in the Isle of Jersey got unmixed varieties of wheat

his own planting and for sale to his neighbors. One of these types is still grown in parts of England and France. (Exp. 1.)

The work of Swedish experimenters

Since this Isle of Jersey farmer conducted his experiments, much similar work has been done both in this country and in Europe. At one experiment station in Sweden the seed from two thousand different plants was saved and planted in as many separate plots. There were more than four hundred heads of oats, each of a different type; hundreds of types of wheat, rye, and other grains; and peas and other seeds as well. These two thousand different kinds of seeds were planted in separate plots, and careful record was kept of the behavior of the plants in each plot from the time of planting until the seed was ripe. Different characteristics were shown. For example, some wheat grew taller than other wheat; some bore more kernels or larger kernels; some developed stronger stems, which were not so easily beaten down by wind and rain; some stood the frost of winter better than others; some were not so subject to disease; some ripened early and some late. From the different varieties the best were selected; the seed was multiplied by replanting, and finally it was distributed to the farmers of Sweden to plant.

How American wheat was improved

In America the most valuable work in seed selection has been done with wheat and corn. At the Minnesota Experiment Station, Professor Hays, by the methods used in Europe, separated several types of wheat from the common varieties grown in the state. These proved to be heavier yielders than the mixtures of which the old varieties consisted.

Work with corn

Dr. Eugene Davenport, of the Illinois Experiment Station, led the way in seed corn selection. He planted the seed from each plant in a separate plot, as the experimenters with small grains had done. But he found that several years of selection were required in order to fix the characters he wished to secure so that the good qualities for which he was striving might not be lost in future generations of the corn.

Why even slight improvement is valuable

In Europe not much corn is raised, and there the farmers have been more interested in the improvement of the small grains. But the United States produces annually a billion or more dollars' worth of corn, and even a very slight increase in the crop would mean an addition of millions of dollars to the total value. Most farmers consider forty bushels an acre a good crop; but by the use of improved methods, yields of one hundred and thirty bushels to the acre have been secured, and even larger yields have been reported (Fig. 69). In view of the rewards for success, corn growers have been stimulated to great efforts to make their fields yield more. In the states of the Middle West and the South, where most of the corn is raised, clubs have been formed among farmers and among boys in the schools for a study of the best methods of raising corn.

Corn clubs

A proof that good seed pays

To show the advantage resulting from the use of good seed, the Iowa Experiment Station took more than five thousand samples of seed corn that farmers were using, raised each sample in a separate plot, and compared the yields. Conditions and treatment were the same for all plots. The production averaged sixty-seven bushels to the acre on the best five hundred plots and forty-two

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FIG. 69. Jerry Moore, of Florence County, South Carolina. Jerry is a wide-awake farmer. South Carolina soil returned him one of the heaviest yields of corn that has ever been reported.

bushels to the acre on the poorest five hundred. A difference, like this, of twenty-five bushels in the yield of each acre is sufficient to repay any care that may be taken in the selection and testing of seed.

Managing a seed-corn plot

For selection to improve seed corn, plots large enough to contain a hundred or more rows with a hundred hills each are laid out. The seed ears are selected from the best ears that the fields have produced, and each row is planted with seed from a single ear. When this seed crop is ripe, the yield from each row is gathered separately and weighed. Ears from rows that have produced the most corn are used for seed (Fig. 70).

A great service that a boy may render

Every county in the corn belt should have its seed-corn specialist who will provide better seed than the farmers, as a rule, will take the pains to develop. The

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FIG. 70. An ear-to-a-row test of corn.

Department of Agriculture recommends that boys undertake this work.

How sugar beets are selected

The sweetest sugar beets are selected to be saved for seed by taking a plug from each one and testing it for sugar. Since the beet-sugar industry began, beets have been improved until they now contain sixteen per cent of sugar instead of six per cent, as they did fifty years ago. Thus the amount of sugar that can be made from them has been more than doubled.

Hybridization

The term "hybridization" is applied to the production of a new kind of plant by putting the pollen from one plant on the stigma of another of a somewhat different kind. (Exp. 2.) The seed of the flower thus pollinated will produce plants somewhat resembling both of the parent plants. A plant produced in this

FIGS. 71 and 72. Pollination: Fig. 71 (left), the complete flower; Fig. 72 (right), applying the pollen by hand. The stamens were removed from this flower before it could develop its own pollen.

way is called a "hybrid" or "cross" and corresponds to a cross-bred animal, — that is, one whose parents are of different breeds.

Pollinating a flower

Pollination by hand is quite possible for any one. The flower that is to be pollinated is opened while in the bud stage and its stamens are removed in order that its own pollen may not reach the stigma. A small paper bag is then tied over the flower so that pollen from other flowers may not be blown on it. At the proper time — that is, when the stigma is full-grown and ripe — the bag is removed and the pollen from the selected flower is sprinkled or rubbed on the stigma (Figs. 71 and 72). The bag is replaced and left on till there is

no danger that the flower will receive other pollen. (Exp. 3.)

Plants that cannot be crossed

Plants entirely different from one another, as the peach and the apple, cannot be made to cross. The pollen of one has no more effect on the stigma of the other than so much dust would have.

Special behavior in natural pollination:

Peculiarities in the reproduction of some plants. Corn bears two flowers on the same stalk, — the tassel, furnishing the pollen, and the ear, bearing the ovules (Fig. 73 and Exp. 5). Each grain of corn has a silk attached to it, the end of which projects from the husk (Fig. 74). Extending down the side of each silk is the stigma upon which a grain of pollen must fall and send its pollen tube all the way back to the ovule. If a grain is shrunken on the cob, it is because no pollen grain reached it. The side of a cornfield that faces the wind is sometimes poorly pollinated and therefore will not bear well. A single stalk or a single row of corn will not do well for the same reason.

(a) of corn

(b) of other plants

In some plants pollen would be injured by dew, and the petals close at night for its protection. In many plants the pollen must be carried to its destination by insects. Two kinds of some plants must be near together, because one furnishes the pollen for the other. This is the case with some strawberries (Figs. 75 and 76). Squashes and melons bear fruit and pollen on separate flowers, but both kinds of flowers are on the same vine (Figs. 77 and 78).

Seedling varieties:

New varieties of potatoes may be secured by planting potato seed (not "eyes." See page 135). But although potatoes often blossom, they seldom make any

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FIG. 73. The two flowers of corn.

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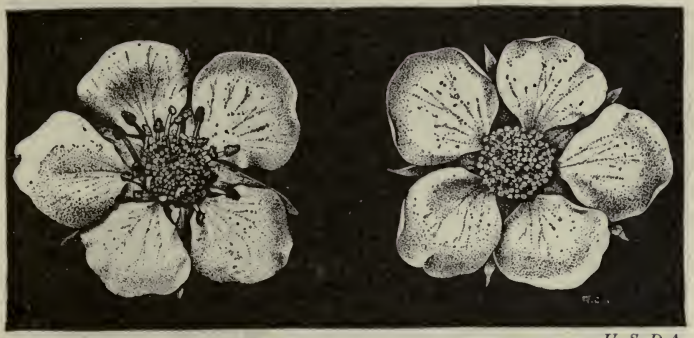
FIG. 74. An ear of corn with husk removed, showing a style (corn silk) attached to each grain.



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FIGS. 75 and 76. A perfect strawberry flower and an imperfect one: Fig. 75 (left), flower with both pollen and stigma; Fig. 76 (right), flower without pollen — only stigma.

(a) of potatoes

seed. Edward F. Bigelow, a naturalist of Sound Beach, Connecticut, managed to collect potato seed from almost every state in the Union and planted it. The result is shown in Figure 79. This is the second year's crop. The first year the potatoes were about the size of peas. The replanting (from eyes) must be continued for several years yet before it can be known whether or not any of the varieties will be desirable. It is said that Luther Burbank, when a young man, originated the Burbank potato by planting seed that he chanced to find on a potato vine.

(b) of fruit trees

Seedling fruit trees differ from the parent tree. And if an orchard were set out with seedlings from the same tree, every seedling might be different from all the others. Whenever a seedling tree is found that has exceptionally good fruit, it can be perpetuated as a new variety by grafting its buds into other seedlings.

W. T. Skilling

FIGS. 77 and 78. Squash flowers: Fig. 77 (left), two flowers with fruit and one with pollen only; Fig. 78 (right), flowers with corollas removed. Flower at left has pollen only. Flower at right has stigma, but no pollen.

Origin of the Washington navel orange

The importation of desirable plants. The United States Department of Agriculture is continually testing new plants brought from other countries. The navel orange is one of the most valuable fruits that it has imported. In 1870 an agent of the Department of Agriculture brought from Brazil some little orange trees of a variety much liked in that country. These were taken to a greenhouse in Washington, where they were multiplied by budding on orange seedlings. Two budded trees thus secured were in 1873 sent to Mrs. Tibbets, at Riverside, California. As soon as these trees bore fruit, the California orange growers saw that they were finer than any variety then grown, and they at once began to take buds from them to graft into their seedlings. These grafted trees, of course, bore

Edward F. Bigelow

FIG. 79. Potatoes derived from seed from almost every state in the Union.

FIG. 80. Transplanting one of the two original Washington navel orange trees. President Roosevelt is shown using the spade.

How it was multiplied

the same excellent kind of fruit, and buds taken from them were used to spread the new variety still further. The Washington navel orange remains the most popular variety on the Pacific Coast, yielding millions of dollars' worth of fruit every year (Fig. 80).

Experiments and Observations

1. Look through a field or garden to see if you can find plants which differ from one another in ways that cannot be accounted for by such influences as more or less room, different soil, cultivation, etc.

2. Examine several different flowers, especially the ovules, stigma, and pollen of each.

3. Cross-pollinate two related plants, as watermelon and citron. Next year plant a seed thus produced.

4. Plant together pop corn and field corn, or red and white corn.

References

"How to Grow an Acre of Corn." Farmers' Bulletin 537.
"Seed Corn." Farmers' Bulletin 415.

CHAPTER EIGHT

FARM MANAGEMENT AND FARM CROPS

I should regard the most valuable of all arts to be the deriving of a comfortable existence from the smallest area of soil.

ABRAHAM LINCOLN

Planning farm work; three points to be considered

THE farmer, like any other business man, must plan his work wisely in order to be successful, and to plan wisely he must understand the principles of farm management. This old subject has been given a great deal of attention during recent years.[1] Among other things, it takes into account matters like the following: (1) What to raise, whether one kind of crop or several kinds. (2) Whether it will be the more profitable to feed crops to stock or to sell the crops. (3) How to keep up the fertility of the land.

The choice of crops

The selection of the kinds of crops most profitable to raise depends mainly on climate and soil. But the selection should depend also upon the prospect of a good market. As a rule the crops most generally raised in a community sell best, for buyers of particular crops go where they can secure large quantities of those crops. There are advantages in raising several crops at once instead of one, as so many cotton and wheat planters do. If one crop fails, the others, perhaps, will not. Moreover, raising several crops permits of rotation, and it distributes the labor of the farm over a longer period of the year, and so helps to do away with periods of overwork and idleness.

[1] Professor W. J. Spillman and Professor G. F. Warren have done much to advance this subject and to make clear its importance.

U. S. D. A.

FIG. 81. A catch crop of cowpeas in corn. The cowpeas will furnish feed for stock, and, being legumes, they will improve the soil.

Four advantages arising from rotation

Rotation of crops. Raising different crops in succession on the same land (rotation) is better than raising one crop continuously, for several reasons: (1) Insects and fungous diseases die out of the soil where the crop upon which they live is changed. (2) If wheat or other small grain is raised continually for several years, the land becomes foul with weeds which ripen seed after the grain is cut. A cultivated crop such as corn, rotated with wheat, gives an opportunity to kill the weeds. (3) Crops like wheat remove large quantities of nitrogen and other plant-food materials from the soil. Rotating such crops with legumes (as clover) will restore nitrogen and allow some of the other plant foods to accumulate.

The following diagram indicates the manner in which

crop rotation is often carried out on Southern farms. *A Southern rotation plan* *A*, *B*, and *C* represent the fields into which a farm is divided. There are three principal crops, and each of these is raised in a different field each year. Cowpeas are planted in corn at the last cultivation and are either harvested with the cornstalks for hay, pastured off, or plowed under (Fig. 81). During the fourth year the arrangement of crops is the same as it was during the first year.

A THREE-YEAR ROTATION

	First Year	Second Year	Third Year
Field A	Cotton	Winter oats followed by cowpeas	Corn with cowpeas
Field B	Corn with cowpeas	Cotton	Winter oats followed by cowpeas
Field C	Winter oats followed by cowpeas	Corn with cowpeas	Cotton

In the corn belt a crop series often used on farms where much livestock is kept is (1) corn, (2) oats, (3) wheat, (4) timothy and clover. A common New England dairy-farm rotation is (1) corn, (2) oats (often sown with cowpeas), and (3) two years of timothy and clover. (Exp. 1.) *A corn-belt and a dairy-farm rotation*

The relative importance of the principal farm products of the United States is shown by the figures for 1917, given on the following page. The first column of figures gives the total value of each crop produced, and the second column (given to aid the memory) shows how much of this value each person in this country would *Field crops produced during one year*

have received if the crop had been divided equally among our one hundred million inhabitants (Fig. 82 and Exp. 2).

(1) Crop	(2) Total Value	(3) Value per Capita	(4) Quantity Produced
Corn	$4,053,672,000	$40.00	3,159,494,000 bu.
Cotton (fiber and seed)	1,866,240,000	18.00	11,449,930 bales (500 lb. each)
Wheat	1,307,418,000	13.00	650,828,000 bu.
Hay	1,359,491,000	13.00	79,528,000 tons
Oats	1,061,427,000	10.00	1,587,286,000 bu.
Potatoes	543,865,000	5.00	442,536,000 bu.
Tobacco	297,442,000	3.00	1,196,451,000 lb.
Barley	237,539,000	2.37	208,975,000 bu.
Sugar	173,490,000	1.73	2,263,113,000 lb.
Rye	100,025,000	1.00	60,145,000 bu.
Rice	68,717,000	.68	51,007,722,222 lb.
Buckwheat	27,954,000	.28	17,460,000 bu.
Flaxseed	25,148,000	.25	8,473,000 bu.
Total crops produced	$13,610,463,000	$136.00	
Total animal products	5,833,386,000	58.00	
Total farm products	$19,443,849,000	$194.00	

To secure the highest success in raising any crop, the farmer should make it the subject of careful study. Here, only a little can be said about several of the more important crops. (Exp. 3.)

The leading American crop

Corn. In the United States corn has been called the "king" of crops. As shown by the figures that have been given, the value of corn is several times as great as that of any other crop, and the quantity raised is about equal to that of all the other grains together.

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FIG. 82. The amounts of the principal grains raised in the United States shown relatively for 1917: *C*, corn; *O*, oats; *W*, wheat; *B*, barley; *R*, rye.

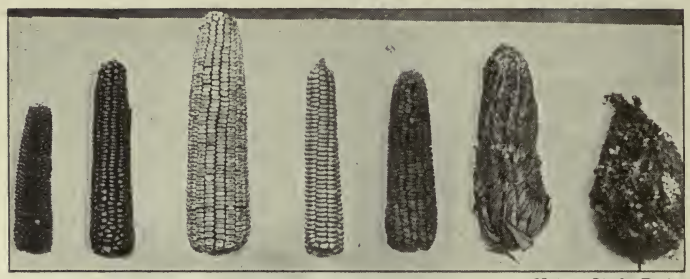
Its chief use is as feed for livestock, and about eighty per cent of it is fed in the neighborhood where it is raised. Only about two per cent is exported. Corn is a native of America. The Indians (who called it "maize," as people in other countries continue to do) were growing it when the early explorers came. It is supposed to be a descendant of a tall, grasslike plant of tropical America. Perhaps this explains why it does best in a climate where there are hot days and nights during the growing season (Fig. 83).

Its origin

Since about fifteen large ears of corn (five quarts shelled) are enough to plant an acre, it is easy to select the seed with care, as directed in Chapter Seven. It has been found that corn will yield a little better if it is planted in drills rather than in hills; that is, one grain in a place and not several grains together. But if corn

Planting and care

Hills or drills



Nature Study Review

FIG. 83. Seven different kinds (species) of corn: pop, flint, dent, soft, sweet, pod, and branched (left to right).

is planted in hills with rows running both ways, it is easier to keep the field free from weeds. To have the right number of stalks in the row and an even stand — no vacant spaces — is very important. It is the safer way, though it requires more work, to plant too thick and then thin to the required number of stalks, leaving the strongest. About ten thousand stalks to the acre is considered the right number in fertile, well-watered soil. This number will be secured if the rows are three and a half feet apart, and the hills three and a half feet apart; with an average of three stalks to the hill. On poorer land two stalks to the hill, or about seven thousand stalks to the acre, will give a better yield. If planted in drills, the stalks should be about fifteen inches apart to give ten thousand to the acre, and twenty inches apart to give seven thousand.

Spacing

Depth

From two to four inches is a suitable depth at which to plant corn. Dry climates require the greater depth (Fig. 84).

Cultivation

Shallow cultivation of corn is best, for the roots are

spread out near the surface (Fig. 85). Little moisture is lost from the surface in a cornfield, for the roots absorb it. But, until late in the season, there must be frequent cultivation to keep the field free from weeds. That cultivation is mainly for the purpose of killing weeds is shown by the fact that, under ordinary conditions, corn will yield about as well if the weeds are scaled off just below the surface of the ground as if the field is cultivated in the usual way (Figs. 86 and 87).

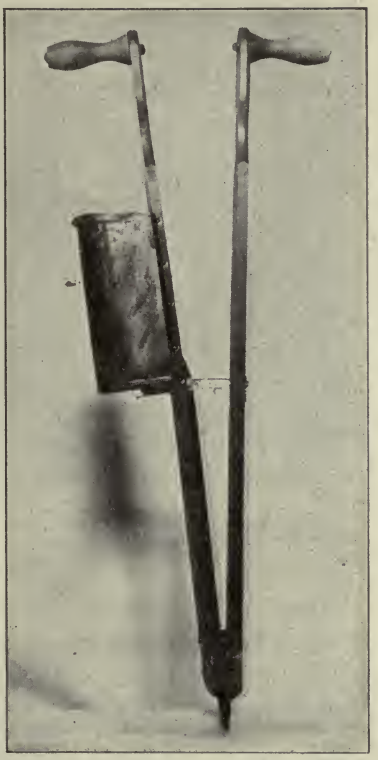


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FIG. 84. A hand corn planter.

Listing

In order to cover the roots to a greater depth, a lister is often used in dry regions. The lister is a plow that throws the dirt in both directions at once, making deep furrows with high ridges between. The corn is planted in the furrows, and as it grows the dirt is cultivated down into the furrows, burying the roots very deeply. Listing is much faster than ordinary plowing, but it does not loosen all the ground.

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FIG. 85. Root distribution of corn at silking time. The bottom of the board represents the surface of the soil. The cultivator should have many small shovels like those indicated at the right of the picture, rather than a few large shovels like the one shown cutting a root at the left.

The production of wheat

Wheat.[1] Throughout the world, wheat is more generally raised than any other cereal. It does well in any temperate climate and stands drought fairly well. The United States ranks first in its production, and it is one of our chief exports. Russia produces nearly as much as we do. Our average per acre is only about fourteen bushels, while in parts of Europe where the farms are small and very carefully tilled the average is more than twice what it is here.

Varieties; when planted

There are a number of varieties of wheat, but they may all be grouped under two headings, — (*a*) winter wheat, (*b*) spring wheat. The former is planted in

[1] The coin with head of wheat, shown on the copyright page of this book, was struck by a Greek city in southern Italy more than 2400 years ago.

U. S. D. A.

FIG. 86. Corn kept free from weeds by scraping the surface of the soil.

U. S. D. A.

FIG. 87. Corn treated like that in Figure 86, except that weeds were allowed to grow.

W. T. Skilling

FIG. 88. Sheaves of barley, rye, and wheat (left to right).

September or October and, after coming up during the mild autumn weather, becomes covered with snow and so lies dormant but green until spring, when it begins to grow again.

Conditions in North and South

In the extreme northern part of the United States the weather is too cold for wheat to live through the winter, and only spring varieties can be grown. In the southern part of the wheat belt, even spring wheat will live through the winter and is sometimes sown in the fall.

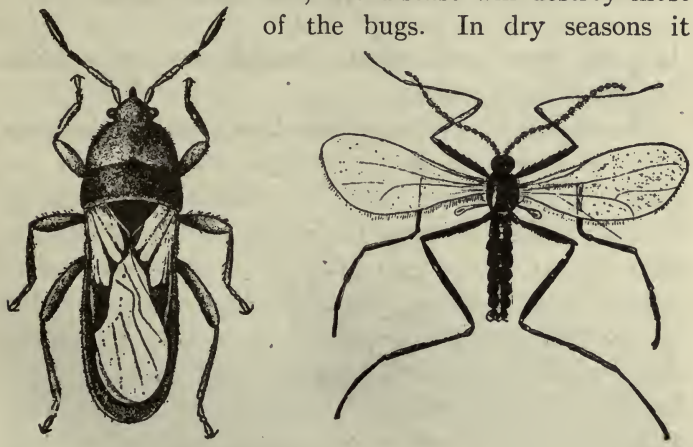
How durum wheat was found

In 1898, the Department of Agriculture sent an explorer to Russia to look for new varieties of wheat. He brought home seed of durum wheat, which has been found to resist drought better than any other variety. It contains less starch and more of the muscle-building

protein than common wheat. It is harder to grind and more sticky when made into dough. But its stickiness makes it so suitable for the manufacture of macaroni and spaghetti that American macaroni is fast displacing the imported article. Bread made from durum wheat flour is more nutritious than other bread, but it has a slightly yellowish color.

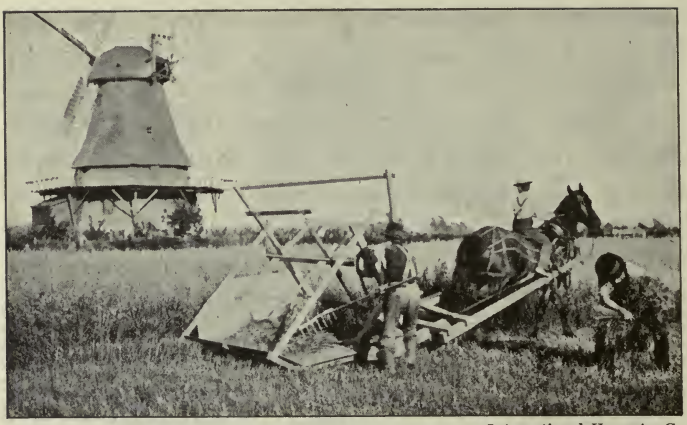
Enemies; the chinch bug

The two chief insect enemies of wheat are the chinch bug and the Hessian fly (Figs. 89 and 90). The experiment stations of the Middle West breed the germs of a disease that is very destructive to chinch bugs. They distribute these germs to farmers whose fields are attacked. If the season is a wet one, the disease will destroy most of the bugs. In dry seasons it



U. S. D. A.

FIGS. 89 and 90. Two of the worst crop pests: Fig. 89 (left), the adult long-winged form of the chinch bug, much enlarged. The chinch bug is especially the enemy of small grains and forage crops. Fig. 90 (right), the adult male form of the Hessian fly, much enlarged. This wheat pest is supposed to have been brought to America in straw supplied to the Hessian troops during the Revolution.



International Harvester Co.

FIG. 91. The first reaper, invented by Cyrus McCormick in 1831. The reaper has helped greatly to remove the dread of famine from the world.

does not have much effect. Rotation of crops holds the chinch bug in check.

Controlling the Hessian fly

The chinch bug is a sucking insect and works very much as plant lice do, by drawing the sap from the plant. On the other hand the Hessian fly, while in the larval stage, damages the wheat by boring into the stem and causing the plant to fall. It is a good plan to delay sowing wheat until after the flies have been killed by the early autumn frosts. Another way of holding the Hessian fly in check is to burn the wheat stubble. But if it were not for certain parasitic insects that live on the Hessian fly and destroy it, we should probably be unable to raise much wheat.

Methods of harvesting

In ancient times a sickle was used to cut the harvest. The threshing was done with a flail or by the trampling of animals. The most modern implement is a com-

bined harvester drawn by a tractor such as was used for the army tanks. This harvester cuts the grain, threshes and sacks it, and drops the sacks off in piles as it moves forward.

Inventions

Some of the steps between these two methods were, first, the invention of a scythe with a cradle attachment for holding the grain as it fell. Then, a reaper drawn by a horse. A man walked beside the reaper and raked the grain off in bunches as it fell on a platform (Fig. 91). Later, men rode on the reaper and bound the grain as it fell. Then the self-binder was invented. After that came the combined harvester (Fig. 92).

The merits of alfalfa

Alfalfa. The hay crop, as will be seen by referring to the figures given, is one of the most valuable crops in the United States. Many grasses and legumes are used as hay, but alfalfa is superior in many respects to all others. It is a legume, and therefore is rich in protein, the feed that builds muscle in growing animals

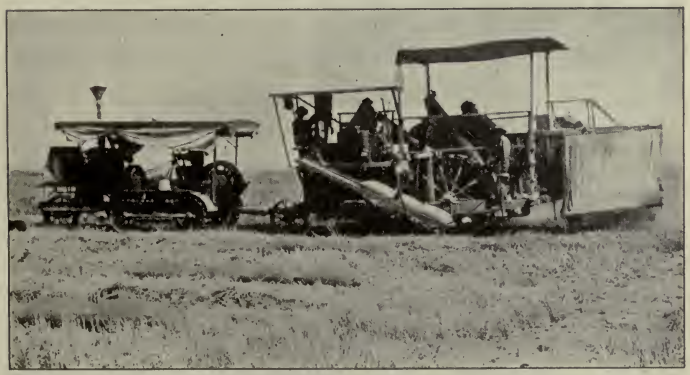


FIG. 92. A combined harvester and thresher drawn by a "caterpillar" tractor. The engine does the work of 25 or 30 horses.

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FIG. 93. A 10-foot alfalfa root. (It extends parallel to the spade handle.)

The soil it needs

and makes milk in dairy cows. There are varieties of it that do well on the dry lands of the West; and few crops are better able to withstand alkali in the soil. Alfalfa is very deep-rooted, and it should have soil at least four feet in depth (Fig. 93). The soil must not be sour. Lime should be added if there is not already plenty in the soil.

Preparing the soil

Since the new plants start slowly, the seed should be put into very thoroughly prepared soil, as free as possible from weed seeds. Young alfalfa plants need a compact soil, and for this reason, after plowing, the ground should be allowed to settle for several weeks before the seed is sown.

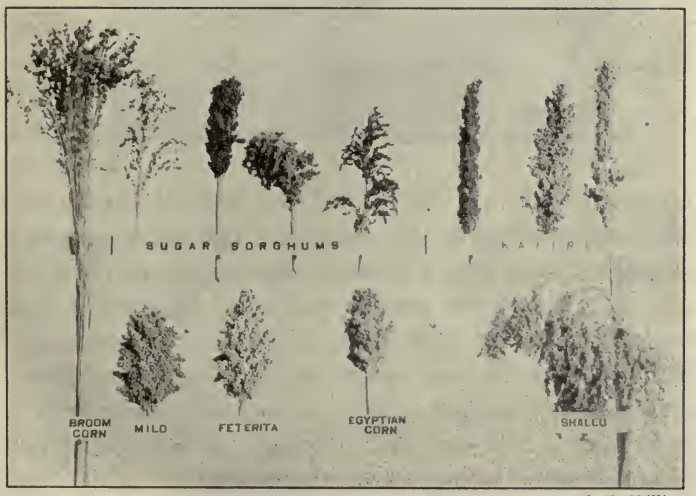
Inoculation

When alfalfa is to be planted in a field for the first time, it is advisable to inoculate the field by scattering over and harrowing into each acre three or four hundred pounds of soil from an old alfalfa field. Or, as we saw

in Chapter Four, instead of being put directly into the soil, the bacteria may be put on the seed by wetting it with a liquid containing them. Throughout the West the bacteria that are essential to the success of the crop are quite commonly found in all soil, and for that reason inoculation is not so necessary there as in the East. In California the bacteria that are needed grow on the roots of a wild legume called "bur clover."

Varieties of sorghum

The sorghums. This large group of plants includes broom corn, the sweet sorghums, kafir corn, milo, Egyptian corn, and others not so well known. Broom corn does not make good feed for stock and it is raised only for the long brush on which the seed grows. The



W. T. Skilling

FIG. 94. Important sorghums: broom corn; sweet sorghums (honey, sumach, planter's friend, and amber — sometimes called "sugar sorghums"); and grain sorghums, including kafir (red, blackhull, pink), milo, feterita, Egyptian corn, and shallu.

The grain sorghums

W. T. Skilling

FIG. 95. Milo (short and thick head) and kafir (long and slender head).

sugar sorghums are useful as feed and also for making sorghum sirup. The sweet juice of the stalk is relished by animals. Kafir corn, milo, Egyptian corn, and some other varieties do not contain much sugar but are very useful as feed. They are spoken of as the "grain sorghums" (Figs. 94 and 95).

Their behavior in drought

The great value of the grain sorghums lies in the fact that they withstand drought better than any other important crop. Their strong root systems search the soil very thoroughly for moisture. During an extreme drought that would kill other crops, their leaves curl, and the plants do not grow much; but when rain comes they uncurl their leaves and begin to grow again. When growth is slow, sorghum sometimes develops a poison called "prussic acid"; so there is danger in letting stock into a field on a hot, dry day, or late in the fall after a stunted second growth has started.

Danger of poisoning

Its introduction

Sudan grass. This grass plant (Fig. 96), like the grain sorghums, was introduced into the United States from a rather dry climate. The Department of Agri-

Its merits

Chamber of Commerce, El Centro, Calif.

FIG. 96. Sudan grass.

culture brought it from the Egyptian Sudan in 1909. Sudan grass is closely related to the sorghums and stands drought even better than they do. Its leaves are sweet, like sweet sorghum, and they are liked by stock. If conditions are favorable, the yield of hay is very large, sometimes being as great as eight tons to the acre.

Experiments and Observations

1. Make a crop rotation plan like the one shown in the diagram in this chapter, but make it for crops grown in your neighborhood.

2. In the order of their importance list the principal farm crops of your county. Make a similar list of farm animals. Where is each product marketed?

3. Using the figures in the third column of the table of farm products on page 104, make a blackboard diagram. Draw on the blackboard a line representing each number in the column. Let one inch represent one dollar.

References

"Corn Cultivation." Farmers' Bulletin 414.

"Smuts of Wheat, Oats, Barley, and Corn." Farmers' Bulletins 507 and 939.

"Better Grain Sorghum Crops." Farmers' Bulletin 448.

"The Feeding of Grain Sorghums to Livestock." Farmers' Bulletin 724.

"Alfalfa." Farmers' Bulletin 339.

"Wheat." Farmers' Bulletins 616 and 678.

CHAPTER NINE

VEGETABLE GARDENING

That wonderful gift which some gardeners seem to have for growing anything is no magic; it comes from the love of plants. . . . And that other gift for making a garden beautiful is no magic either; it comes of loving the garden as well as the plants.

Tropical Agriculturist

The value of a garden in country or city

On many farms there is little or no garden, for the farmer finds it hard to take part of his own time or that of his men from the fields. He says that he can buy vegetables cheaper than he can raise them. The usual result of not raising them, however, is that the farmer's family does without vegetables. And in the cities vacant lots are allowed to grow up in weeds, while the comfort and health of many families would be increased by the supply of fresh vegetables and berries that might be secured from these lots (Fig. 97).

How the young gardener is benefited

Every family in town and country should, if possible, have a garden, not only because it is profitable, but because the satisfaction of having one's own vegetables fresh every day is reward enough for the work required. The boy who furnishes his own or neighboring families with vegetables that he himself raises is doing something to build up the kind of character that he needs in life. The girl who does a little work in her garden every day is adding to her physical strength and is laying the foundation for health.

Improvement of soil

Preparing garden soil. Gardening is the most intensive kind of farming — the greatest amount of produce is taken from the smallest area. The richest soil

W. T. Skilling

FIG. 97. A sale of garden vegetables that were raised by pupils on the grounds of a city school.

is needed to make a garden pay for the labor and time that is expended upon it; but even if the soil is naturally poor, it can be so improved as to produce fine results. If the soil is a stiff clay, hard to work and liable to bake badly, it may be greatly improved by working into it several loads of sand. Also, if air-slaked lime is applied at the rate of a ton to the acre or about five pounds to one hundred square feet, it makes such soil looser and much easier to work, and it overcomes sourness. (Exp. 1.) It is said that a French gardener can make a successful garden on the top of a building. All that he needs for it is a few loads of earth and plenty of fertilizer.

Two effects of lime

Well-rotted barnyard manure is a safe fertilizer for any soil or crop. It may not possess in large enough proportions some of the needed plant foods, but it has some of all of them. Besides, it changes into humus and so makes the physical condition of the soil better. Market gardeners sometimes use as high as 40 tons of

Manure; amount allowable

manure to an acre. This would be at the rate of about two pounds to the square foot.

A complete fertilizer

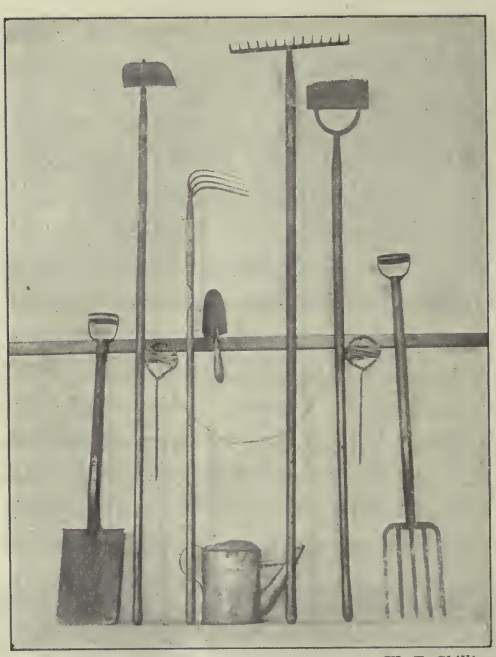
Artificial fertilizers are also much used. From one thousand to two thousand pounds of any high-grade "complete fertilizer" may be applied to each acre. A complete fertilizer is one made up of potash, phosphates, and nitrates. Special fertilizers are sold, containing these ingredients in proportions suitable for particular crops as potatoes, strawberries, etc. The potato crop, for example, needs a large amount of potash.

Why careful preparation of soil is necessary

Garden seeds are so small and the plants, as a rule, are so much more delicate than are those of field crops, that the soil needs to be finer and the surface smoother than is necessary in the fields (Fig. 98). The plowing or spading should be deep in order to give the roots plenty of room in which to search for water and nourishment.

W. T. Skilling

FIG. 98. Keep a furrow when spading, and rake while the clods are soft.



W. T. Skilling

FIG. 99. Tools enough to start a garden.

Much time is saved by the use of a "wheel hoe" in gardening (Figs. 100 and 101).

Methods of applying manure

Stable manure may be spread over the surface of the ground, and mixed with the soil when the garden is spaded or plowed. The most effective way to apply manure is to put it into a trench and mix it with the soil under each row of vegetables. It is said that the Indians used to bury a fish under each hill of corn at planting time.

The start for a garden

Hotbeds and cold frames. Even before the frost is out of the ground in spring we may begin garden opera-

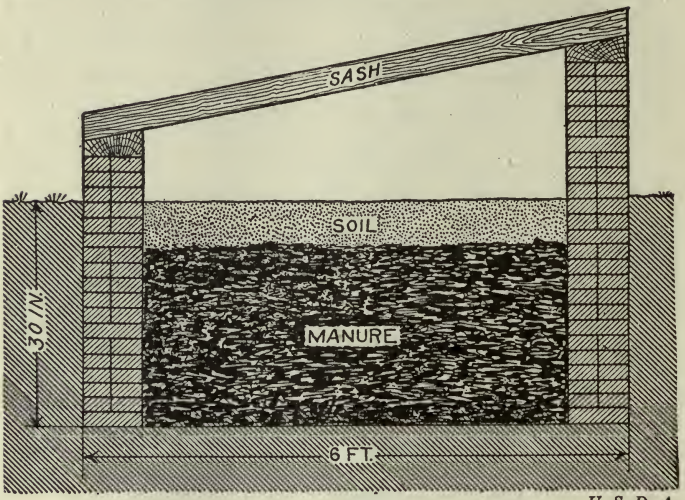
S. L. Allen & Co.

FIG. 100. A wheel hoe, combining weed cutters, cultivators, rakes, and plow.

W. T. Skilling

FIG. 101. With a wheel hoe, in soft ground, three boys or one man can do as much in an hour, either in preparation, planting, or cultivating, as in a day with ordinary tools.

tions. A hotbed makes it possible to begin raising cabbage and tomato plants in March. The plants will



U. S. D. A.

FIG. 102. How a hotbed is constructed.

be well grown by the time it becomes safe to set them in the open ground.

Making a hotbed

The process of making a hotbed is very simple (Fig. 102 and Exp. 2). Fresh horse manure is piled on the ground to a depth of about two feet, leveled off, and covered with six inches of garden soil. The heat generated by the manure is sufficient to keep the soil warm for five or six weeks. Fresh cow manure may be used if mixed with plenty of straw, as it usually is in the stall. A wooden frame is built around the plot and a glass cover is placed on the frame. Regular hotbed sash with small panes can be purchased to make this glass cover. The frame should be a few inches higher on the north side,

so that the glass will slope toward the south, thus admitting the largest possible amount of sunlight as well as draining off the rain. Sometimes a permanent hotbed is made by digging a pit thirty inches deep and bricking up the sides. This has only to be refilled each year.

A cold frame

The chief purpose of a cold frame is to protect plants from frost. It is similar to a hotbed, except that no manure is put into it to supply extra warmth (Fig. 103). The frame is sometimes covered with cloth instead of glass.

Four advantages in the use of a hotbed or a cold frame

There are several reasons why it is often better to start plants in a nursery, such as a hotbed or cold frame, than to plant them in the garden directly. First, as already noted, time can be gained while we are waiting for weather warm enough for outdoor planting. Second, an early, quick-growing crop such as radishes can be

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FIG. 103. Sash-covered cold frame.

raised in the garden while a crop like celery or cabbage is being prepared in the hotbed. This second crop can be transplanted as soon as the first is out, thus economizing in the use of land. Third, the young plants can be better and more easily cared for in a small seed bed than in the open garden. Fourth, transplanting causes a better root system to form (Fig. 104). The broken roots branch more freely, just as a rose stalk, the tip of which has been pinched off, will immediately send out side branches along its whole length.

Starting tomato plants

Tomatoes. Late in March or early in April tomato seed may be planted in a hotbed or in a house that is heated. The plants will be ready to remove to the garden in May or as soon as danger of frost is past. While still in the hotbed they should be transplanted

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FIG. 104. At the left are the roots of transplanted celery; at the right are the roots of celery that was not transplanted.

FIG. 105. Transplanting tomatoes. When the hole has been dug, the ground should be well watered before the roots are covered. The plants will do better if they are kept shaded during the first few days after they are set out.

twice to prevent them from crowding each other and becoming weak and spindling.

When transferred to the garden the plants will be almost large enough to bloom (Fig. 105). They should be set three feet apart in rows four feet apart. Or, in rich garden soil, they may be six inches closer than this each way.

Care

Fermenting manure dug into the garden soil will be of benefit in furnishing some heat as well as in giving nourishment. Unless the vines are trained up on a support, a little hay or straw should be placed on the ground for them to rest upon. This will keep the fruit clean and make it less likely to rot.

Pruning

In August, if the plants are growing rapidly, it is well to prune off the ends of the vines so that the nour-

ishment that they would take will go into the fruit and develop it more perfectly.

Planting and fertilizing cabbage plants

Cabbage. Like tomato plants, cabbage plants are usually raised in a hotbed and transplanted to the field or garden. Cabbage grows very fast while heading, and it therefore requires an abundance of nourishment. If manure is too scarce to be spread all over the ground, it should be put around each plant and worked into the soil, or before transplanting it should be buried where each plant is to be placed.

What the cabbage butterfly does

One serious pest is the cabbage worm, which is so nearly the color of the leaf that it can scarcely be seen. It is hatched from eggs laid by a white or slightly yellow butterfly with black markings on its wings (Fig. 106). This is the butterfly that is often seen flitting from one cabbage plant to another to deposit its eggs. The butterfly itself does no harm. Lead arsenate may be sprayed on the plants before the heads begin to form. If spraying is properly done even after the heads have formed, there is no danger, for it has been determined that as many as twenty-eight heads of cabbage so sprayed would have to be eaten to cause poisoning. The only danger is in using an unnecessary amount of the spray. An even safer spray, however, is tobacco extract. This will destroy not only the worms but also plant lice, which often injure the cabbage crop.

Spraying

The climates to which beans and peas are native

Beans and peas. Beans have been grown since ancient times in the warm countries that border on the Mediterranean Sea. The varieties we raise are supposed to have originated in the warmer parts of South America. As might be expected, beans are known as

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FIG. 106. Cabbage butterflies. The female has two spots on each wing; the male, one.

a warm-season crop. Peas, on the other hand, are supposed to have originated in the cooler parts of the Old World. They are a cool-season crop. They can be planted much earlier in the spring than beans, for they will stand considerable frost and will grow rapidly in weather so cool that beans would be at a standstill.

Why there are many varieties of both

There are many varieties of both peas and beans, for the flowers readily cross-pollinate and new hybrids result. The dwarf types of both peas and beans should be planted, unless supports can be provided for the high-climbing varieties. The latter bear the more abundantly, however. The smooth varieties of peas are more hardy than the wrinkly varieties, and they will also endure more frost.

Smooth and wrinkly peas

Planting beans and peas

Beans should be planted shallow — not more than an inch deep; but peas can be planted as deep as four inches. The bean plant comes up double, bringing the seed with

W. T. Skilling

FIG. 107. Gathering a 50-dollar crop of string beans in a school garden.

it, and it is not able to break through a great thickness of earth. The pea seed, on the other hand, remains in the ground, and the tightly rolled plant pierces the ground easily. Both beans and peas are usually planted in drills, but the climbing varieties may be planted in hills for convenience in arranging supports (poling).

Fertilizers required

Beans and peas belong to the family of leguminous plants. They do not require much nitrogen in the soil, since, like all legumes, they can get it from the air through the bacteria in their root nodules. But wood ashes, ground bone, or any other fertilizers rich in potassium and phosphorus are very beneficial.

When to grow lettuce

Lettuce. This vegetable, like cabbage, is a cool-season crop. It thrives best in early spring or late summer. It stands considerable cold. If grown in

hot weather, it should have shade to keep it crisp. Lettuce is often sown broadcast, but it is better to start the plants in a nursery. In the garden they should be set about a foot apart each way. The varieties that form close heads are much superior to those that develop loose leaves, but the head varieties are more difficult to raise. *Methods of planting*

The vine crops. Melons, squashes, pumpkins, and cucumbers resemble each other very much in manner of growth and in the kind of care they require. Most of the rules for successfully growing one of them will apply to the others.

Since the vines are warm-climate plants, it is necessary to delay planting in the spring until the soil is well warmed; otherwise the seed will rot. Plenty of fertilizer is needed to secure a good vine crop. A shovelful of manure buried where each hill is to be planted gives the vine a quick start. The manure is covered with dirt and well packed, so that moisture will rise through it. The seeds are then planted over the manure. The depth of planting varies with the size of the seed. Cucumbers and muskmelons should have only half an inch of moist earth over them. The larger seeds, as of squashes and pumpkins, may safely be put a little deeper. *The season for vine crops* *Planting and fertilizing*

The distance that the hills should be apart depends somewhat on the richness of the soil. In heavily fertilized land the vines run more and so should be planted farther apart than in poor soil. Muskmelons, cucumbers, and summer squashes are planted from four to five feet apart each way. Watermelons, pumpkins, and winter squashes require double this distance. *Space between hills*

Plants to each hill

Thinning, after the plants are well up but before they have begun to run, is very necessary. To insure a good stand, ten or twelve seeds are often planted in each hill; but this number must be reduced to two or three before the plants begin to crowd each other. In the case of watermelons, one vine in a place is better if large melons are wanted.

Securing an early crop

In order to secure an early crop that will bring a higher price, the young plants are sometimes raised in a hot-house and then removed to open ground. But since they are very difficult to transplant, they cannot be handled like tomato and cabbage plants. They must be raised in little pots, berry boxes, or on small squares of sod, and they must be moved without disturbing the roots (Fig. 108).

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FIG. 108. Cucumbers planted in a berry box.

Enemies

The protection of vines against the common pests — squash bugs, cucumber beetles, and plant lice — is considered in Chapter Thirteen (Fig. 109).

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FIG. 109. The striped cucumber beetle (much enlarged). The larva attacks the roots and stems of vines; the adult eats the leaves.

Planting to get the best stand of sweet corn

Sweet corn. In planting and caring for sweet corn, the requirements are very little different from those for field corn. The rows are usually three feet apart, and the hills are three feet apart in the row, with three stalks to the hill. The same number of stalks may be distributed, one in a place, along the row. The yield will be about the same in either case. If several grains are dropped in a hill, they should not be bunched closely together. If the corn is planted thicker to make sure of a good stand, it should be thinned early.

Securing a continuous supply

A succession of plantings from about May 1 to July 1 makes it possible to have sweet corn during all the latter part of the summer and through the early fall. Some varieties mature in about two months; others require nearly three. The late varieties as a rule grow larger, produce more, and are sweeter than the earlier varieties.

The corn-ear worm

A troublesome insect is the corn-ear worm. It is much more destructive in the South than in the North. Its mother, a gray moth, lays her eggs on the silk of the young ear. From here the worms, when hatched,

How it may be checked

crawl into the ear, eating the grains as they go. The best means to combat this pest is to raise a variety of corn with a thick, close-fitting husk, such as the evergreen, and to keep the corn well watered and growing rapidly while the ears are forming. As a partial remedy the silks may be dusted several times with arsenate of lead in the form of a fine, dry powder.

The soil best suited for beets and similar crops

Underground crops; beets, etc. Beets, carrots, parsnips, and salsify (oyster plant) are much alike in the culture and soil that they require. A deep, sandy loam is best for them, for if the ground is hard the roots are likely to branch and become irregular in shape. A heavily fertilized soil is very desirable; but in fresh manure the roots tend to branch, and it should not be used.

Time to plant

These are all "cold-loving crops" and should be planted early in the spring. The seeds should be planted about an inch deep in rows sixteen inches apart. Parsnips and salsify are slow to come up. A few radish seeds are sometimes planted with them to mark the row, so that cultivation may be started early. The radishes will mature before the other plants need the room. Parsnips and salsify require the whole season to mature.

Thinning

Beets may be thinned twice: first when they are about six inches high and will do for greens, and later when the roots are large enough to put up in bunches for sale. The remaining beets, now about four inches apart, may grow to full size for winter use. Carrots, parsnips, or salsify, if too thick, should be thinned soon after they come up, so that they will have room enough to grow to their full size without crowding.

Potatoes. White or "Irish" potatoes are grown both as a field crop and as a garden vegetable (Fig. 110). Light sandy loam is the soil most suitable for them, though they will grow in any soil and in almost any climate.

The best soil for potatoes

That part of the common potato which we eat is not a root, but it is a tuber — an enlarged underground stem. And the "eyes," which are planted to produce the new crop, are really buds. Each eye will grow, and even a scrap of peel containing an eye will produce a plant. But it will not do well unless there is enough substance with the eye to furnish nourishment for the plant while it is getting its root system established. Experts say that each piece into which a potato is cut for "seed" should be as large as a small egg (Fig. 111).

What the eyes of the potato are

It is the better plan to select seed potatoes while they

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FIG. 110. Digging and picking potatoes. On large farms 4-horse riding diggers are used.

W. T. Skilling

FIG. 111. Potatoes should be cut to the size of a small egg for planting. (Egg at left of picture.)

Why seed potatoes should be selected at digging

are being dug. Then they can be chosen from healthy plants that have produced the largest number of good, uniform potatoes. Seed selected from the bin, though good looking, may have been produced on vines that bore only a few good potatoes, and therefore a crop grown from them would be poor.

Caring for seed tubers

Potatoes for seed should be kept in a fairly light, dry room. Any sprouts that form in the light will be short and sturdy, not easily broken off in planting. Sprouts formed in the dark are soft and long. Badly sprouted

Planting

tubers should not be used as seed. Potatoes should be planted in rows three feet apart, with the hills fourteen to eighteen inches apart in the row, four inches being

about the proper depth. One piece of seed potato containing an eye should be planted to each hill.

Insects and diseases; the potato bug

Both the vines and the tubers of potatoes are attacked by insects and various diseases. The Colorado potato beetle ("potato bug") is the commonest and most destructive insect pest. It lives on the leaves and so can easily be killed with a poison spray of Paris green.

Use of formalin to prevent scab

A common disease of the tubers is potato scab. This is a fungous growth that causes the potato skin to appear rough and unsightly. If potato seed is not perfectly smooth, it should be treated with formalin to kill the fungi that might cause disease in the new crop. The treatment consists in soaking the potatoes for two hours in water containing formalin, one pint of formalin to thirty gallons of water being the right strength.

Potato blight

A disease of the potato vine which causes it to wilt and die is known as "potato blight." This is also a fungous disease, and it can be prevented by spraying the potato vines every ten to fourteen days with Bordeaux mixture, the spray that is used for most fungous diseases. Potato blight does not occur in all parts of the United States. A sudden outbreak of blight in Ireland many years ago, before any remedy was known, resulted in a famine that cost the lives of more than two hundred thousand people.

Conditions for growing sweet potatoes

Sweet potatoes. That part of a sweet potato which we eat is a true root and not an underground stem like the tuber of the white potato. As sweet potatoes are natives of tropical America, they are especially a Southern crop, though they are grown in the North in warm,

sandy soil. In the South the large, juicy varieties known as "yams" are preferred, while in the North the smaller, drier kinds are better liked. Sweet potatoes will grow in almost pure sand, but they need a good deal of moisture.

Sprouting and setting out

In starting the plants a hotbed is used. The plot is covered with a layer of the potatoes laid about half an inch apart, so that any rot that starts in one will not spread to others. The potatoes are then covered with four or five inches of sand or light soil. Many sprouts come up from them, and when these sprouts are about six inches above ground they are carefully pulled. The potatoes are left in the hotbed to produce more sprouts. The first pulling yields ten or twelve sprouts from each potato. In the South "slips" for later plantings are obtained by cutting the ends off earlier vines. Sprouts or slips should be set about sixteen inches apart in ridges three feet apart. The vines will spread over all the ground. During cultivation they should be moved with the hoe to prevent them from taking root (Fig. 112).

Keeping

Sweet potatoes must be fully ripe to keep well, and they keep best in a warm place. A test for ripeness is made by breaking a potato in two. If drops of water form at the broken ends, the potato is not ripe.

Methods of propagating onions

Onions. Where many onions are to be raised, it is customary either to plant seeds or to transplant young seedlings from a nursery. But onions may be most

Growing sets

quickly grown from sets. These are raised like ordinary onions, but they are planted thicker — about two hundred seeds to the foot in each row — and usually upon land not very rich or very well supplied with

moisture. Under these conditions the bulbs cannot grow large.

Planting seeds

In growing onions from seed, the seed is planted in rows a foot apart, and at the time of the first weeding the plants are thinned so as to leave them two or three inches apart in the row. The plants are very delicate at first, and they do not come up well if a crust is allowed to form over the surface of the soil.

An onion nursery

If the nursery method is used, the seed is sown thickly in a carefully prepared plot and the seedlings are transplanted while still very small. The plot should be level, well enriched, and bordered with a ridge of earth so that it can be flooded with water if necessary. In cultivating onions, care should be taken not to cover the bulbs with soil.

W. T. Skilling

FIG. 112. The yield of a single hill of sweet potatoes. The larger varieties, called "yams," yield much more heavily than do the smaller varieties, like those in the picture.

The soil that onions need

Three soil conditions necessary to the best results in growing onions are richness, mellowness, and freedom from weeds. These conditions can best be secured by

heavily fertilizing and thoroughly cultivating the soil for several years before the attempt is made to raise onions. A ton of manure should be applied to a plot thirty feet square each year that onions are raised on it.

How drought affects them

A regular supply of moisture is very necessary for onions, as they are shallow-rooted plants. If their growth is checked by drought at any time before they are nearly full-grown, they do not recover as readily as some crops do when rain comes. (Exps. 3 and 4.)

Gathering the crop

Onions, except when raised for use as "green" or "bunch" onions, should not be pulled before the leaves have begun to ripen off. When pulled, the bulbs should be spread in a cool, dry, and well-ventilated place.

Yield

A single acre will yield as many as five hundred or even eight hundred bushels of onions. But as onions require much more care than do most other crops, the return for the labor expended is not so high as one might expect it to be.

Fungous diseases

Smut and mildew of onions are two serious fungous diseases which may be held in check by spraying with Bordeaux mixture.

Experiments and Observations

1. Thoroughly mix a little lime with a handful of dry clay. Wet the clay and roll it into a ball. Make a similar ball of clay without lime. Let each dry and see which crumbles more easily.

2. Build a hotbed in March and raise such vegetables as tomatoes and cabbages.

3. Secure seedsmen's catalogues and find descriptions of the different varieties of vegetables that have been mentioned. Discuss these descriptions in class. What garden tools do the catalogues advertise?

4. Make a garden according to the instructions given in this chapter. Raise at least one row of each of the vegetables considered.

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"Potato Culture." Farmers' Bulletins 407 and 533.
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CHAPTER TEN

ORNAMENTAL GARDENING

Great, wide, beautiful, wonderful world,
With the wonderful water around you curled,
And the wonderful grass upon your breast —
World, you are beautifully drest.

WILLIAM BRIGHTY RANDS

WHETHER one's home is in the city or in the country, it should be beautiful, and it can be made so. Even a small lawn, a few flowers, some clumps of shrubs, and a tree or two add to the feeling of comfort in a home and increase its money value as well (Figs. 113 and 114).

How a landscape gardener regards the lawn

The lawn. Some one has spoken of the lawn as "the canvas upon which the landscape artist places his picture." Flowers, trees, shrubbery, and buildings do not appear to the best advantage without an expanse of green to serve as a setting.

Grading

The lot should be carefully graded before grass is planted, for the surface of the lawn cannot well be made even or given a different slope after sod is formed. If the ground is naturally level, it should be sufficiently built up near the house to give it a gentle slope toward the street. This slope should be convex; that is, it should have a slight bulge. The convex form makes a lawn look larger, while a concave or dished surface makes a lawn look cramped and small. Another means of making the lawn appear prominent is to make walks and drives less noticeable by having them a little lower than the general level of the grass.

How to make the lawn look as large as it should

W. T. Skilling

FIG. 113. A house and lot.

W. T. Skilling

FIG. 114. A home; the house and lot in Figure 113, after plants were set out.

The final slope

Frequently a lawn is given a gentle slope almost to the sidewalk and then is made to drop off steeply to the edge of the walk. It is nearly impossible to keep the grass in proper condition on such a sharp incline. The slope should be about the same all the way, or the drop at the sidewalk should be vertical, with a retaining wall.

Preparing the soil

It is much easier to store a large amount of fertilizer in the soil while it is being prepared for grass than to apply the fertilizer little by little afterwards. Well-rotted stable manure is the most satisfactory fertilizer to apply. It makes humus, which, as we know, helps

Fertilization

the ground to hold moisture and furnishes nitrogen and other plant foods. It is well to add a little lime and ground bone to the stable manure. The lime sweetens the soil if it is sour, and the bone slowly decomposes and furnishes the grass with phosphorus. Two pounds of manure and an ounce each of lime and ground bone may be applied to each square foot of lawn.

The different grasses for lawns

Kentucky blue grass is more commonly used for lawns than is any other grass. Bermuda grass is much used in the South, especially on light sandy soils. Italian rye grass makes a quick lawn, but it is coarse and soon dies out. Redtop, bent grass, and white clover are used east of the Allegheny Mountains where the soil is too acid for other grass. White clover is usually planted with Kentucky blue grass, as the two make a more satisfactory lawn than does either grass alone.

Sowing

Grass seed should be sown thickly, so that weeds will not have much room to get a start. If there is too much grass, some of it will be crowded out in time and no harm will be done. Where a combination of

blue grass and white clover is wanted, the seeds should not be mixed before planting. The mixture would be uneven, for the clover seed is heavier and would settle to the bottom.

Caring for the lawn

After the grass comes up, the ground should be rolled to give it a smoother, firmer surface. The lawn mower should be used as soon as the grass is high enough for the blades to reach it. Cutting the grass early makes the growth stronger. To keep it fresh and of a good color, it should never be allowed to go to seed. To prepare the lawn for winter, it is a good thing to give it a mulch of well-rotted manure. This should be thin enough so that the winter rains and snows will wash it down out of sight about the roots of the grass.

How to place shrubbery

Shrubbery and trees. The beauty of a place is increased by the presence of shrubbery if it is well arranged. The most inartistic arrangement is one in which the shrubs are regularly spaced, and only a little better is a miscellaneous scattering of shrubs over the lawn. It is best to group the shrubbery in clumps at corners and along the edges of the lawn, leaving unbroken as wide an expanse as possible (Fig. 115). A bend in a walk makes a good place for a clump. Against the

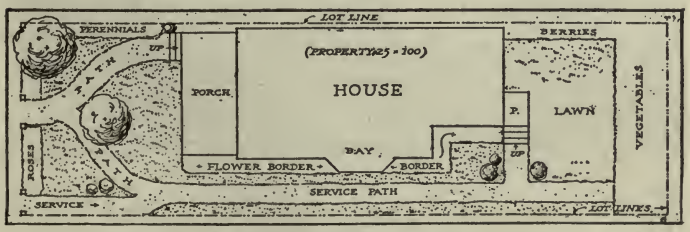


FIG. 115. An artist's plan for improving a city yard.

FIG. 116. The shrubbery and flowers are well arranged about this American colonial-style home. Note the unbroken lawn and the hydrangeas placed against the foundation of the front porch.

FIG. 117. Farmhouse on "Model Farm" at the Panama-California Exposition. Note the arrangement of flowers within the circular widening of the walk. The house is built in mission style, which is popular in the Southwest. This manner of building was suggested by the architecture of the old Spanish missions.

FIG. 118. Transplanting and pruning a young fruit tree. A tree should be set in a large hole, plenty of water should be applied, and the pruning shears should be used freely.

foundation of the house there should be low shrubs or vines (Fig. 116).

Why shrubs need constant pruning

Shrubs should be pruned vigorously, for a great deal of cutting induces new growth and so keeps the plants looking fresh and green. Pruning encourages shrubs to send out branches all the way down to the ground. This covers the stems, that otherwise would be bare, and causes the whole mass of foliage to appear to rest upon the lawn.

The beauty of trees

A few trees lend a touch of dignity to a place which flowers and shrubbery, however beautiful, cannot give. But it is a mistake to have the house very densely shaded by trees, pretty as this may look, for sunshine in abundance is necessary to health (Fig. 117).

Much of the success of a tree depends upon its start

How to plant a tree

(Fig. 118). When the tree is removed for transplanting, plenty of earth must be allowed to adhere to the roots so as to preserve the root hairs (see page 3). Upon planting, the roots are well spread out in a large hole so filled that the best of the soil is in the bottom. To prevent the tree from being bent by the wind, it should be supported by a stake (Fig. 119). Plenty of water should be poured on the soil that is filled in, in order to settle it. After the first watering the soil should be kept only damp. Too much water may rot the roots.

Many inexperienced persons think that pruning away any of the foliage at transplanting will retard the growth of a tree. But there is no surer way to stunt a transplanted tree than not to prune it. (See page 81.) In

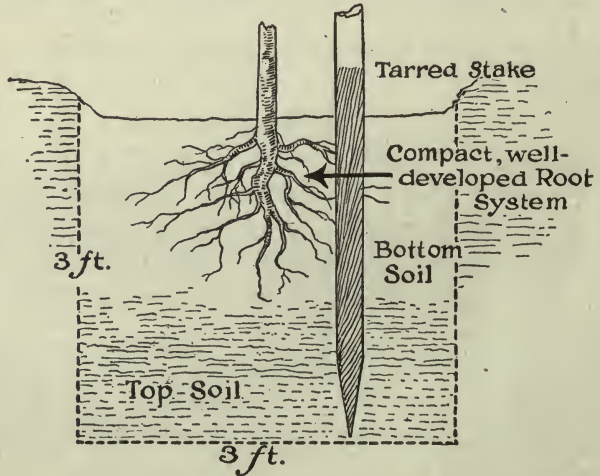
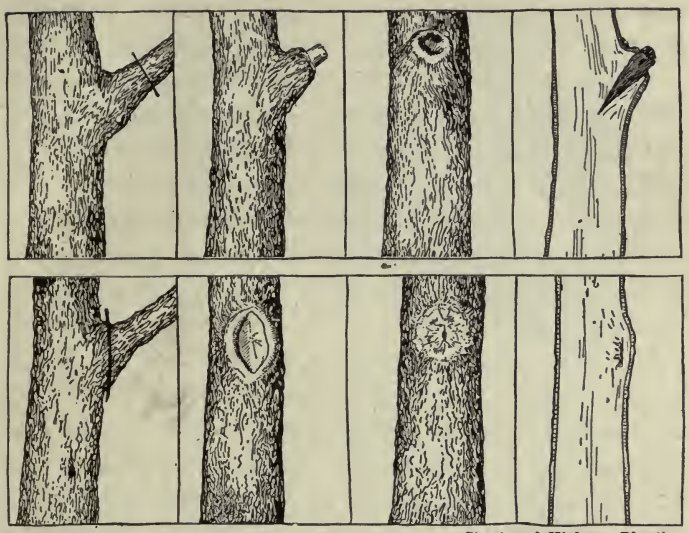


FIG. 119. The roots of a small tree that has been properly transplanted. The supporting stake is shown in position at the right. Notice dimensions of hole and location of topsoil where the roots can grow down into it.



Street and Highway Planting

FIGS. 120 and 121. If a stub is left when a branch is removed, decay is very likely to enter the trunk of a tree. But if a branch is cut off close to the trunk, the wound will heal over.

Pruning trees or shrubs; where to cut

pruning either trees or shrubs, if a branch is to be removed the cut should be made close up to the trunk or limb that supports the branch (Figs. 120 and 121). If a short stub is left, it will die, and decay may spread from it as shown in Figure 120. For the same reason, if only part of a branch is to be removed, the cut should be made just beyond a bud.

Effective arrangement of flowers

Flowers; the rose garden. Flowers are the gems for which the garden furnishes a setting, and their effectiveness depends very much upon the way in which they are arranged. Some flowers are most attractive standing alone; some look well in a mass; others, as daisies, do best if they are allowed to grow as wild flowers do, here

and there in the grass. Low flowers may well be planted in a row bordering a walk. The tall hollyhock and the golden glow look best, perhaps, if banked against a wall. Where several kinds of flowers are planted in a clump, the tallest should be placed farthest back, so that they will not hide the lower flowers (Fig. 122).

The place for roses

A warm, protected spot on the sunny side of the house is a good place for roses. They need the protection in winter, and the sunshine helps to keep off mildew in summer time.

The queen of flowers

The rose suffers more than most flowers do if not properly treated, but to good care it responds with lavish beauty. For best results the rose should be grown in clay soil, with an abundance of fertilizer. But when first planted there is danger of the roots decaying if they come in contact with manure or any decaying substance in the soil. To supply fertilizer, a hole two feet deep may be dug and partly filled with a mixture of manure and

Planting and care

soil. The rose is planted above this food supply in clean earth or, better, in leaf mold. The top should be nearly all pruned away, and any broken or bruised roots should be removed by making clean cuts.

Mildew is a fungous growth which attacks some

FIG. 122. Flowers properly arranged against a wall. The taller each variety is, the farther back it is placed.

varieties of roses. It may be held in check by dusting the leaves with powdered sulfur. The sulfur sticks better if it is put on when the leaves are wet with dew.

Sulfur for mildew

The older stems of the rose bush are often seen to be covered with a soft, white substance that looks somewhat like mildew (Fig. 123). The appearance is caused by a multitude of very small scale insects which suck the juice from the stem. They may be killed with a wash or spray made of washing powder dissolved in water — one pound to five gallons.

Spraying for rose scale

FIG. 123. Rose scale. The female scale insects attach themselves permanently to the plant. These and the young suck the plant juices. The adult males do not feed, having no mouth parts; they have one pair of wings.

Another rose pest is plant lice. These insects work on the soft growing tips of the stems. Like the scale insects, they suck plant juices, but they crawl about, while the scale insects (at least the wingless females) are fixed permanently to the bark. The simplest way to control plant lice is to spray them off the bushes with a garden hose.

Plant lice (aphids)

A water garden. Pond lilies add a touch of distinction to a garden, and on a small scale one may have a lily

How to make a pond

pond at little cost. The simplest way to make a pond is to sink several tubs side by side in the ground. Lily bulbs are planted in boxes of rich earth set at the bottoms of the tubs. The tubs are filled half or two thirds full of good soil that has been mixed with well-rotted manure, and are then filled to the top with water. At a little more expense a small cement pond can easily be made (Fig. 124).

Preventing green slime

When the pool has once been filled, the water does not need to be renewed, but enough water must be added to make up for evaporation. We may keep the pool from becoming filled with algæ (green slime) by putting a little bluestone in the water. The bluestone will not hurt the lilies, but as little of it

Lee Passmore

FIG. 124. These lily pools are lined with cement. Though few of us could have so large a water garden, most of us could have gardens that would be beautiful.

as possible should be used if there are fish in the pond.

Why fish should be kept in the pond

A few goldfish should be kept in the pond to prevent mosquitoes from making it a breeding place. The fish eat the wigglers, which are the larvæ of mosquitoes. The plants supply the fish with oxygen for breathing, while the fish exhale carbon dioxid gas which the plants use for growth.

Water plants in winter

The common pond lily and many other water plants are so hardy that they will live over winter in a pond. The bulbs and tubers of more tender varieties may be removed to a cellar. This is easily done if the pond is so arranged that it can be drained.

The bulb garden. Many of our most beautiful flowers are raised from bulbs instead of from seeds. Most of the bulbs are hardy enough to remain in the ground over winter, ready to come up with the first warm days of spring. The pure white snowdrops bloom, often, before the last snow has melted. They are quickly followed by the crocuses, which come in several colors. Later come the yellow daffodils and the gorgeously colored hyacinths and tulips.

What a bulb is

A bulb is an underground portion of the stem or it consists of thickened leaves, and its purpose is to furnish an abundant store of food that the plant may draw on during its period of rapid growth when it is sending up a flower stalk. The onion is a good example of a bulb. The year in which the seed is planted is spent in maturing the bulb. If this is left in the ground or replanted after being kept over winter, it blooms and produces seed.

A common example

There are three kinds of bulbs: (1) those which, like

Kinds of bulbs

the onion and the hyacinth, are made up of thin, broad coats; (2) those made of thick, narrow scales like the lily; and (3) solid bulbs (or corms), of which the gladiolus and crocus are examples.

Suitable garden conditions

The soil for bulbs should be a sandy loam rather than a heavy clay soil such as roses need. It should be very fertile, but no manure except that which is thoroughly rotted should be used. Bulbs (except those of water plants) need good drainage. Soggy, water-soaked soil is bad for them. Nearly all bulbs require sunshine. A few, however, as tulips and hyacinths, will develop taller stems if grown in the shade.

Planting and care

A large proportion of the bulbs sold in the market are grown in Holland. The common bulbs, such as crocus, tulip, and the like, are for this reason often spoken of as Dutch bulbs. October is the best month to plant them, for if they are put into moist earth then, they will have time enough before the ground becomes frozen to get their roots established in the earth and to draw a supply of nourishment for use as soon as spring comes.

How to treat bulbs that have bloomed

After the bulbs have bloomed, the faded flowers should be removed, for there will be a serious drain upon the plant if they are allowed to go to seed. The most exhausting process in the life of any plant is the production of seed. Annual plants die when their seed is ripe. After the leaves begin to fade, the tops should be cut off. Then the bulbs may be left in the ground if it is moderately dry, or they may be removed and stored until planting time. Bulbs multiply in the ground, and at transplanting time they should be separated.

When bulbs are grown in a dish of water, as is some-

Water-grown bulbs

times done, they should be removed to the ground after blooming. This allows them to regain strength, and unless this is done they will either not bloom at all or bloom very poorly during the next year. Whenever the water in which house bulbs are grown is changed, it is well to add a few drops of ammonia. The ammonia will supply the plants with nitrogen and make their growth more vigorous.

Experiments and Observations

1. Sketch a plan for the grounds around a house, showing walks and the locations of the different kinds of trees, shrubs, and flowers. What do you think of the plan given in Figure 115?

2. Look carefully at the grounds of some public building in or near your neighborhood and report to the class on the arrangement of trees, shrubs, etc. Tell what improvements, if any, you think might be made. (The grounds about some home might be considered to better advantage if there were no danger of giving offense.)

References

"Beautifying the Home Grounds." Farmers' Bulletin 185.
"Lawn Soils and Lawns." Farmers' Bulletin 494.

CHAPTER ELEVEN

DRY FARMING AND IRRIGATION

The desert shall rejoice, and blossom as the rose.

ISAIAH

Eastern farming methods not successful in the West

IN the western half of the United States there are many places with so little rainfall that good crops cannot be raised by the methods used in the eastern half of the country. When the West was first settled there were many crop failures, because the farmers, who had come from the East, had not learned what changes they needed to make in the methods that they had successfully used where rain was plentiful.

Two Western methods

Two systems of farming have now come into use in the West: dry farming and farming with irrigation. It is possible to produce much larger crops and a greater variety of them if irrigation can be used, but there are many places where, as yet, the farmers cannot get water for irrigation. In such regions a fair yield of certain crops can be secured by dry-farming methods, provided the rainfall is not too small.

Conditions required in dry farming

Dry farming. It must not be thought that dry farming means farming without moisture. No crop will grow without water, and the ordinary farm crops require three hundred pounds or more of water to make one pound of crop. That is, this large amount of water must pass from the roots up through the stem and be lost by evaporation from the leaves in order to produce enough plant substance to weigh a pound after it is dry. It is known that a large sunflower leaf has about thir-

teen million stomata, out of which water vapor escapes, and that a sunflower as tall as a man may, by transpiration, lose as much as a quart of water in a day. It has been found that at least ten inches of rainfall is necessary in most places to produce even a fair crop. However, the amount necessary is different in different places, for loss by evaporation from the soil will be much greater where there is much wind and hot weather than where there is less wind and a cooler temperature. The soil, too, must be deep enough to absorb all the rain that does fall. The depth down to bedrock should be at least five or six feet.

How much rain is necessary

Depth of soil

The practices which, taken together, make the system called "dry farming," are all for the purpose of making a light rainfall go as far as possible toward producing a good crop. They are of use in gardening as well as in growing field crops.

Methods

In dry regions where there is summer rainfall, the ground should be plowed as soon as a crop is harvested. (For the practice where there is little or no rain in summer, see page 160.) The plowed ground will absorb any rain that falls instead of allowing it to run off. The deeper the plowing, the larger will be the reservoir of moisture for use by the next crop. Tests made with fall wheat during seven years at the Kansas Agricultural Experiment Station, Manhattan, Kansas, show clearly the advantage in plowing deep and early. The fields used for the tests were similar. The different yields per acre were due to the different preparation of the seed bed in each case. The results (averaged for the years 1911 to 1917) were as follows:

Summer plowing

The advantage in plowing deep as well as early

Time of plowing	July 15	Aug. 15	July 15	Sept. 15	Sept. 15	Disked at seeding time
Depth of plowing (inches)	7	7	3	7	3	
Yield per acre (bu.)	22.1	20.7	17.1	14.8	13.6	7.8

Keeping a dirt mulch

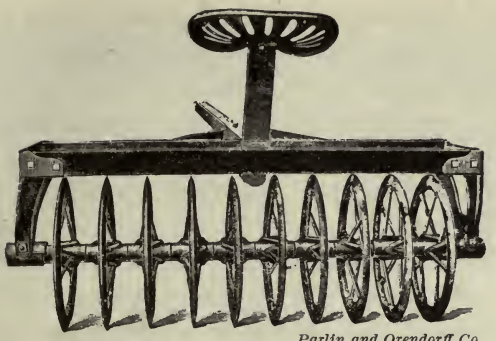
To have the soil retain as much as possible of the water that it has absorbed, the surface must be kept loose. This lessens the amount of moisture that can rise between soil particles through capillary attraction. (Exp. 2.) The surface should not be allowed to pack down or to crust over; so frequent harrowing or other shallow cultivation is necessary, especially after each rain. Instead of a roller, a subsurface packer is used to pack the soil. This firms the lower soil but leaves the surface loose (Fig. 125).

The lesson of a horse track; the subsurface packer

It is said that H. W. Campbell, who has done much to teach the methods of dry farming, observed that wheat grew better in horse tracks than in other parts of a field. He noted how the horse, in treading, packs the soil, and that, as it withdraws its foot, loose dirt falls into the hole, making a dirt mulch on the surface. It was Mr. Campbell who invented the subsurface packer, to do for all the ground what the horse's hoof does for a small spot.

Deep planting

The deeper the roots can be made to grow, the better they are able to obtain moisture. The Indians in New Mexico understood this before white men did. They made holes in the ground with stakes and dropped the seed corn into the holes. White men sent to teach them



Parlin and Orendorff Co.

FIG. 125. A subsurface packer. The heavy wheels with V-shaped edges pack the dirt against the subsoil but leave the surface loose.

modern agriculture were not as successful in raising crops as were the Indians; but this was before the scientific principles of dry farming had been worked out.

Thin planting

Still another point of difference between farming in a humid and in a semiarid region is that only about half as much seed may be used in the dry region as in the humid region. The reason for this is that every plant takes from the soil a certain amount of moisture and if there are too many plants all of them will wilt for lack of water, whereas the same amount of moisture might be sufficient for the growth of fewer plants to the acre.

Choice of crops

It is of greatest importance that crops be grown which are able to withstand drought well. Among those most suitable for dry farming are wheat, oats, rye, barley, corn, potatoes, and the various kinds of sorghum. The most drought-resistant of these is the sorghum family. The introduction of grain sorghums (milo and kafir corn) into the semiarid West for use as stock feed has revolutionized farming there.

Behavior of different varieties of the same crop

Certain varieties of each of these crops are better adapted to a dry climate than other varieties of the same crop. For example, durum wheat, which was brought from the semiarid plains of the Volga in Russia, has proved itself to be an excellent dry-farm wheat, and in some sections little else is grown. In Arizona a plant called the "tepary bean," growing wild and used as food by the Indians, has been found to bear well where other beans would fail for lack of water.

Fallowing

"Fallowing" is a method of allowing the soil to accumulate more than the ordinary supply of water and plant-food material before a crop is planted. There is in the ground a great deal of plant-food material that is not in soluble form so that the crops can absorb it. But much soluble food material is constantly being made from the humus and the minerals of the soil. This will accumulate if the ground is plowed, allowing air to enter it, and if no weeds are permitted to grow for a season.

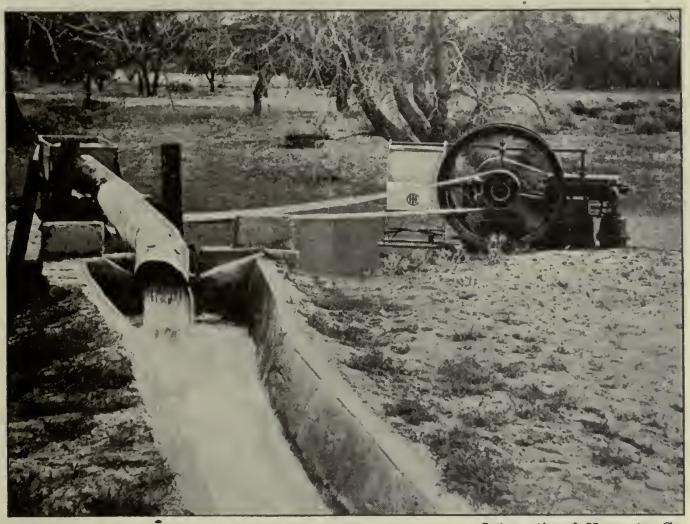
How it makes a better crop possible

Summer fallowing in the West

In the dry farming regions of the West, plowing for summer fallow is done late in the fall or early in the spring. The land is left bare till the following fall, and it is kept free from weeds. It is then usually sown to winter wheat, thus missing a crop during the year of the summer fallow. This is particularly the practice on the Pacific Coast. While the land is being fallowed in regions that will have summer rainfall, it should be harrowed after each rain to prevent packing at the surface and consequent loss of moisture.

Leaching

There is much less loss to the soil by leaching in a dry region, of course, than in a region of heavy rainfall; but where the ground is dry, much of the humus



International Harvester Co.

FIG. 126. Pumping water for irrigation. A portable gasoline engine furnishes the power. In parts of China and Egypt, human power is still used for such work.

changes to gases and escapes into the air. Therefore, to keep up the supply of humus, it is well to plow under, when possible, such waste crop materials as straw. It should be kept in mind, however, that one can, in dry regions, get an excess of vegetable matter into the soil. The soil will then be too light and it will easily dry out and blow away.

Supplying humus

Irrigation. Water to irrigate with is often pumped, either from wells or streams (Fig. 126). Gasoline engines, electric motors, or windmills are used to operate the pumps. Windmills are slow, and they are unreliable on account of the irregularity of wind. Gasoline motors give plenty of power but require much more attention

Sources of water for irrigation; pumping

FIG. 127. The main ditch of an irrigation system on a sugar plantation in Hawaii.

than do electric motors. The latter will run day and night with no one near.

Artesian wells

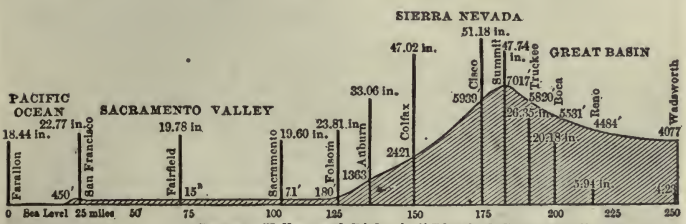
In some favored localities there are artesian wells, from which large streams flow continually.

Damming streams

A large irrigation system intended to supply water to many farms is made by damming a stream several miles above the land to be irrigated. A lake forms back of the dam, and an open ditch or sometimes a large pipe leads the water out of it and down the valley (Fig. 127). But instead of following the channel of the stream, this ditch runs along one side of the valley. It is given enough fall to make the water flow, but not so much fall as the stream bed has. In this way the water in the ditch is soon many feet above the natural stream bed and may be allowed to flow out over the farms that are below it in the valley.

Mountain rainfall; why it is heavy

Much of the water of streams and wells falls as rain in the mountains and flows either underground or above



Gregory, Keller, and Bishop's "Physical Geography." Ginn & Co.

FIG. 128. On mountain slopes that receive the wind from the sea, the rainfall is very heavy. Near the summit it is heaviest. On the side of the mountains away from the sea, the rainfall very rapidly diminishes. Note that at Colfax, California, which is perhaps 32 miles to the west of the summit of the Sierras, the rainfall is 47.02 inches, while at Reno, Nevada, which is about 30 miles to the east of the summit, the rainfall is only 5.94 inches.

ground to the lowlands. Highlands often receive several times as much rainfall as lowlands, for the cold air of the mountains is needed to condense the moisture of the air into raindrops. The heaviest rainfall in the world, five hundred inches annually (over forty feet), is in the highlands of India. Figure 128 shows how the rainfall in California depends on elevation. The same air that blows across the Sacramento Valley, giving about twenty inches of rain, gives forty-eight inches when it has reached the summit of the Sierra Nevada Mountains. At San Diego, on the coast, the rainfall is ten inches a year, while upon mountains which are within sight of the city the rainfall is fifty inches. Much of this mountain rainfall would be wasted if it were not for irrigation systems.

The United States Reclamation Service is engaged in reclaiming desert lands. Its work is on "govern-

FIG. 129. The Roosevelt Dam. While such a dam is being constructed, the river is generally carried out of its course by means of a tunnel that pierces the mountain side.

ment projects." ("Carey Act projects" are works of reclamation undertaken by private companies under state supervision by an arrangement with the Federal government.) Already thirty irrigation projects furnish water for three million acres, upon which in one year crops worth eighty million dollars are raised.

The Roosevelt dam

One of our largest dams is in Arizona, across the Salt River. It was built by the government and was named in honor of Theodore Roosevelt, who in 1911 formally opened its floodgates (Fig. 129). The water held back by the dam makes a lake from one to two miles wide and twenty-five miles long. This irrigation system furnishes water for two hundred and twenty

thousand acres. Besides this, it gives water power capable of generating electricity enough to do the work of nearly ten thousand horses. The largest dam in the West is the Elephant Butte Dam across the Rio Grande River. It irrigates parts of Texas and New Mexico. The highest, though not the largest, dam in the world is the one at Arrow Rock, across the Boise River, in Idaho. The largest masonry dam in the world is the Assuan Dam in Egypt across the Nile River. It is one hundred and twelve feet high in the highest place and is more than a mile long.

The dams at Elephant Butte and Arrow Rock

The Assuan Dam

The principal ways of using irrigation water are sprinkling, furrow irrigation, level check flooding, and hillside flooding.

Four ways of irrigating

Gardens and other small tracts are often watered by sprinkling with a garden hose. Sometimes a system of overhead pipes is run above the area to be watered, and the gardener has but to turn on the water. In very hot weather, if plants are sprinkled during the middle of the day the leaves may be scalded. The late afternoon is a better time to sprinkle.

Sprinkling

The chief objection to sprinkling is that usually not enough water is applied at once. Whatever method of irrigation is used, the water should flow until the ground is thoroughly soaked to a depth of two feet or more. Then it should not be necessary to repeat the irrigation for at least ten days or two weeks. If the surface of the ground is kept wet, and the soil below is allowed to become dry, the roots will spread out near the surface. Thoroughly wetting the ground to a good depth and allowing it to become dry on top encourages the roots to

The effects of surface and deep wetting compared

FIG. 130. Furrow irrigation near Richland, Idaho.

grow down. And deep-rooted plants get more plant food and do not suffer so much from an occasional dry spell.

Furrow irrigation; advantages

Running the water in furrows between the rows is usually more satisfactory than sprinkling (Fig. 130). It wets deeper than sprinkling often does, and as it leaves the foliage dry it does no harm on a hot day. The water in the furrows should run slowly enough so that it will just reach the lower end of the row before the last of it sinks into the ground. In watering orchards several furrows are made between two rows of trees, but in watering such a crop as potatoes one furrow for every other row is sufficient if the water is allowed to run long enough. The best way to make sure that all the ground is wet to a sufficient depth is to use a spade.

Arrangement of furrows

Check flooding

The check system of flooding a field is suitable only where the ground is nearly level. Before the crop is

planted, the whole field is laid off like a checkerboard in areas small enough so that each one can be graded perfectly level. Each level area or "check" is surrounded with ridges of dirt, so that water several inches deep can stand on the check until it soaks into the soil. One or more of the checks may be flooded at a time, depending on the amount of water available. Sometimes the checks consist of strips fifty or a hundred feet wide and perhaps a quarter of a mile long, made level from side to side, but sloping from end to end. Water is flooded in at the upper end of the strip, and the gentle slope carries it through to the other end, thoroughly soaking the whole area. The check system is often used for alfalfa fields. The water destroys

Grading

Applying the water

W. T. Skilling

FIG. 131. A miner's inch flowing. The water level is kept 4 inches above the hole.

many gophers, which make themselves a pest by burrowing in cultivated fields.

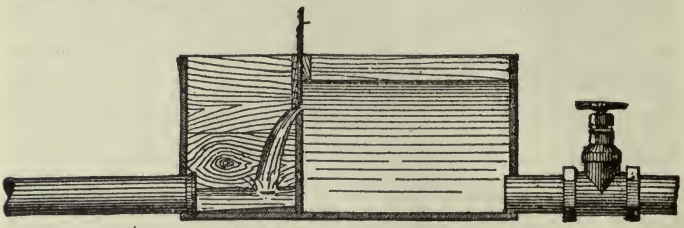


FIG. 132. A box used for measuring irrigation water. Each inch in width of opening allows the escape of one miner's inch.

Hillside flooding

Sloping land is often flooded without either furrows or checks. The water is carried along the upper part of the field in a trench, which may be winding in order to have a gradual fall. The sides of the trench are broken at places with a shovel, so that the water may flow out and spread over the whole surface of the field. This method of flooding is suitable for such crops as grain, where furrows would be troublesome.

Measuring water for irrigation; the miner's inch

There are several methods of measuring irrigation water in order to know how much to pay for it, but in most irrigation districts water is paid for by the " miner's inch," a unit of measurement that was used by the Western miners in pioneer days (Figs. 131 and 132). It is the amount of water which, flowing continuously, can pass through a hole an inch square if the middle of the hole is four inches below the surface of the water in the measuring box. In some states the depth of water used is four and a half or five inches. Of course, the deeper the water stands above the outlet, the more the pressure and the faster the flow.

The acre foot

Another measure according to which the farmer may be charged for the water he uses is the "acre foot." The acre foot is the amount of water necessary to cover one acre a foot deep. This is equal to 43,560 cubic feet.

The measure for rivers

A way of stating the measure of water where large quantities are flowing, as in a river, is to tell the number of cubic feet per second passing a certain point.

Experiments and Observations

1. Pour water on freshly spaded ground and on uncultivated ground. Notice the difference in absorption.

2. To show that water rises in packed soil, make footprints in freshly cultivated soil and notice early on the next morning that the surface in the tracks is wet while the surface of the loose ground is dry.

3. Find weeds or other plants growing alone and notice how much larger they are than similar plants where the stand is thick.

4. To illustrate a miner's inch, make a water-tight box and cut an inch hole in one side near the bottom. Run water into it fast enough to keep the water level four inches above the middle of the hole (Fig. 131).

References

"Management of Soil to Conserve Moisture." Farmers' Bulletin 266.

"Practical Information for Beginners in Irrigation." Farmers' Bulletin 864.

CHAPTER TWELVE

SUPPLYING SOIL NEEDS

What Nature asks, that Nature also grants.
JAMES RUSSELL LOWELL

Soil needs

AN Illinois farmer, who had spent his life in an unsuccessful attempt to raise profitable crops, wept when he was shown that the addition of one fertilizer (potash) would have made his fields fertile. Every farmer should find out whether or not his land is naturally lacking in any of the essential plant-food materials and how he can remedy such lack (Fig. 133). He should also find out what necessary elements his fields are losing and how he can replace the loss (Chapter Four).

Commercial fertilizers

The three elements most commonly needed as fertilizers are, as we have already seen, nitrogen, phosphorus, and potassium. These are all found in manure. They are often supplied, either singly or mixed, by fertilizer dealers, who get them, not from manure, but from certain minerals or from slaughter-house refuse. When supplied in this way they are called " commercial fertilizers," and a mixture of all three of these necessary plant foods is called a " complete " fertilizer. (Exp. 1.) Two other plant-food elements, calcium (contained in lime) and sulfur, are sometimes necessary.

Commercial names

Nitrogen, phosphorus, and potassium are most commonly used in compounds known as " nitrates," " phosphates " (or " phosphoric acid "), and " potash "; and fertilizers containing the three elements are often loosely referred to by these names of their compounds.

To show how many pounds per acre of the three

Nature Study Review

FIG. 133. The lack of a single plant-food element prevents growth. In the first jar of pure sand, none of the essential elements has been added; in the second jar, all except nitrogen have been added. The third jar lacks only phosphorus; the fourth contains phosphorus and lacks only potassium (chemical symbol K). The fifth jar contains all the necessary plant-food elements. Except for these differences, the five lots of corn grew under exactly the same conditions.

The amount of plant-food material a crop requires

principal plant-food elements each of several different crops requires in one year, the list below is given. It is taken from Dr. Hopkins' work on *Soil Fertility and Permanent Agriculture.*

	NITROGEN	PHOSPHORUS	POTASSIUM
100 bushels of corn	148	23	71
100 bushels of oats	97	16	68
50 bushels of wheat	96	16	58
25 bushels of soy beans . . .	159	21	73
400 bushels of potatoes	84	17.3	120
25 tons of sugar beets	100	18	157
8 tons of alfalfa	400	36	192

How crops differ in the kinds of food material that they remove from the soil

From this list it would appear that some crops exhaust the land of a given element much faster than other crops do; for example, a beet crop removes a large amount of potassium. Apparently alfalfa and beans, requiring more nitrogen than any other crops mentioned, would very soon exhaust the soil of this valuable food. But it will be remembered that both alfalfa and beans belong to the family of legumes and are able to take nitrogen from the air as well as from the soil.

Two ways in which nature robs the soil of nitrogen

Nitrogen. Excepting the legumes, plants take nitrogen mainly from the humus of the soil, and not from the air. The soil more often lacks nitrogen than any other plant-food element. Nitrogen is a substance that readily leaches out of the soil, its compounds being very soluble, like salt or sugar. Not only is nitrogen drained away by water, but under some conditions it escapes in large quantities into the air as a gas. Experimenters found that in a field growing grain continually, six times as much nitrogen was lost from the soil each year as was required to make the crop. Twenty-five pounds were removed with the grain, and one hundred and fifty pounds escaped into the air and in the drainage.

How lack of nitrogen affects plants

Where the supply of nitrogen is low, plants will be of a pale green color and their growth will be poor. More than any other plant-food element, nitrogen promotes the growth of leaves and stems.

Supplying nitrogen

Nitrogen may be supplied to the soil either by raising a leguminous crop such as clover or field peas and plowing it in, or by adding a fertilizer containing nitrogen.

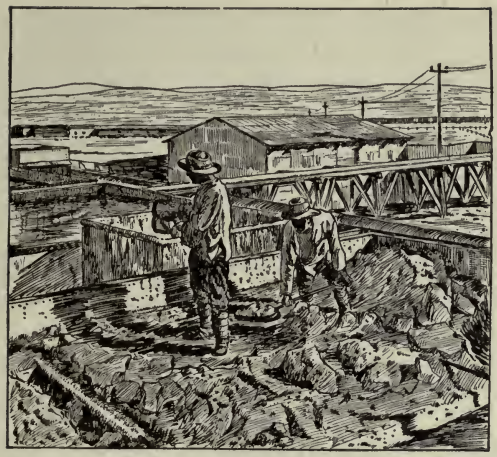


FIG. 134. A sodium nitrate refinery in the desert of northern Chile. Chile once fought a war with Peru and Bolivia for the control of the nitrate fields.

When to apply a nitrogen fertilizer

A nitrogen fertilizer should be put into the soil at the time of planting or just before planting, so that the plants may secure their nitrogen while they are young. If the nitrogen is given after the crop is partly grown, it will stimulate new growth of leafy material and the fruit will be late in maturing. On the other hand, if it is applied too early it is liable to be washed out and lost.

Nitrate of soda

The simplest form of nitrogen fertilizer is a substance called "saltpeter" or "nitrate of soda." (Exp. 2.) It looks very much like common salt, but it contains a large amount of nitrogen (one sixth of its total by weight). Unfortunately this salt is becoming very scarce. The only very large supply of it is found in northern Chile along the "rainless coast" (Fig. 134). The sodium nitrate, or "Chile saltpeter," lies in beds from a few inches

to twelve feet in thickness. It is dug up and purified by separating from it the common salt that is found with it. It is then shipped from Valparaiso to many parts of the world. About three fourths of it is used for fertilizer, and much of the rest is used for making explosives.

A fertilizer made from ammonia

Household ammonia contains nitrogen and is often put into water that is used on house plants. But as it evaporates so readily, ammonia is not suitable for use as a field fertilizer. It is easily changed, however, to a solid compound called "sulfate of ammonia." This is done by adding sulfuric acid to the ammonia and evaporating the mixture. (Exp. 3.) The dry, solid sulfate of ammonia, looking like salt, is left. This is a very valuable fertilizer. It contains more nitrogen than any

Illustrated World

FIG. 135. Sulfate of ammonia, an important nitrogen fertilizer, made as a by-product in the manufacture of coal gas and coke.

Robert Cushman Murphy

FIG. 136. Part of a guano field on an island off the coast of Peru. The birds are pelicans and cormorants, the principal producers of guano.

How nitrogen came to be stored in coal

other fertilizer. Ammonia is mostly made from coal as a by-product when illuminating gas is manufactured. Coal can be made to yield this nitrogen compound because coal was formed from vegetable matter. The coal-forming plants took the nitrogen from the soil millions of years ago (Fig. 135).

Guano

Guano is a valuable commercial fertilizer that consists of the dung of sea fowls or bats. A good quality of guano contains nitrogen, phosphorus, and potassium, in compounds. Most of the old deposits of guano have been exhausted. The supply that continues comes for the most part from a number of islands off the coast of Peru, where the guano-producing birds are carefully protected by the government (Fig. 136).

Packing-house fertilizers

In large meat-packing establishments there are enormous quantities of offal. The offal fat is made into grease; but the bones, horns, and hoofs (after the glue products have been extracted), and the blood and animal waste are cooked and dried for use as fertilizers. Of these products the dried blood is the richest in nitrogen and the quickest to give up its nutriment to plants.

Dried blood

The nitrogen in the air

If plants were able to absorb nitrogen directly from the air and use it as food, they would have an abundance, for four fifths of the air is nitrogen. The air presses down upon every square inch of surface with a weight of nearly fifteen pounds. About four fifths of this weight is due to nitrogen and this gives almost twelve pounds as the weight of nitrogen upon each square inch. As ordinary plants are unable to use this gas, chemists have invented several methods for making it unite with other elements in compounds suitable for plant-food material. One of these methods consists in passing strong electric sparks through the air, making nitrogen and oxygen unite. From this compound a good fertilizer can be made. In Norway, water power equal to the strength of a quarter of a million horses is used to generate electricity for capturing nitrogen from the air.

The electrical method of fixing nitrogen

The Haber process; fixing nitrogen under pressure

The latest and most efficient method of fixing nitrogen was invented by a scientist named Haber. In his process hydrogen gas is mixed with nitrogen of the air, and the gases are subjected to great pressure. They unite to form ammonia, which is easily changed into a good nitrogen fertilizer. This process is not limited to countries having enormous water power, as the electric method is. The machinery used can be driven

by steam engines. The Haber invention gives promise of an increased fertilizer supply, and therefore of an increased food supply for the world.

The work of nitrogen-fixing bacteria

What it takes the greatest skill of man and the most powerful machinery to do, the nitrogen-fixing bacteria in the nodules of legume roots are quietly and continually doing all over the world — changing the nitrogen gas of the air, which the plants cannot use, into compounds which they can use (Chapter Four).

Phosphates

Phosphorus. The form in which phosphorus is usually found in fertilizers is phosphate of lime; that is, phosphorus combined with lime. Bones are composed largely of phosphate of lime. Phosphorus in mineral form is distributed throughout the earth, but it is always combined with other elements. Pure phosphorus glows in the dark, and it takes fire spontaneously if left exposed to the air. A compound of phosphorus is used in the manufacture of matches.

Loss of phosphorus from the soil

Phosphorus is but slightly soluble, and it is, therefore, not so easily lost from the soil by leaching as nitrogen is. A crop of forty bushels of wheat raised on an acre will remove twenty-eight pounds of phosphoric acid from the soil, the grain taking twenty-one pounds and the straw seven pounds.

Sources of commercial phosphate fertilizers

Bones and phosphate rocks are the two materials out of which the phosphate fertilizers of commerce are made. Phosphate rock is found in Florida and other Southern states, and bone comes from the meat-packing establishments. Both bone and rock have to be ground fine to be of use, and even then the phosphate dissolves very slowly in the soil. To make it more soluble, the

Superphosphate

material is treated with sulfuric acid. It is then called "acid phosphate" or "superphosphate." The acid that is used is neutralized by the lime in the bone or rock, so that it does no harm to the soil.

Potash

Potassium. There are large quantities of potassium in the soil, but it is always in compounds. And most of these are so insoluble that the plants cannot benefit by them. For this reason it is often necessary to fertilize the ground with soluble potash compounds, which the plants can readily absorb.

Potash-loving crops

Clover and the other leguminous crops need potash, and fruit trees in bearing should be well supplied with it. More than half of the mineral matter of fruit is potash. The potato, also, is a potash-loving plant.

Sources of potash

To obtain potash as a fertilizer, the simplest method is to use wood ashes. (Exp. 4.) But the supply of these ashes is very limited, and coal ashes do not contain enough potash to make them of any value. The chief commercial source of this fertilizer is a vast deposit of various potash salts near Stassfurt, Germany. During the war we could not get German potash, and for that reason began to develop our own potash resources. Most of the home supply has been obtained from the brine of salt lakes in Nebraska, Utah, and California.

Why lime may be lacking

Lime. In nearly all regions of heavy rainfall, lime, which is somewhat soluble, is likely to be deficient in the soil (Fig. 137). In such places crops would be greatly benefited by its use. Lime is applied rather to improve the soil than to supply a plant-food material, though it serves both purposes.

When used on soils that need it, lime has the follow-

U. S. D. A.

FIG. 137. The white heaps consist of lime that is ready to be spread over the field.

Five benefits from the use of lime

ing effects: (1) In clay soil it binds the fine particles together into larger particles. Thus the clay becomes like a sandy soil. It loses its stickiness and does not bake so badly. It becomes easier to cultivate. (Exp. 5.) (2) It furnishes calcium, one of the ten elements that are essential plant-food materials. (3) It "sweetens" a sour soil. (See page 34.) (4) It is useful to the beneficial bacteria in the soil, as these cannot thrive in a sour soil. (5) It aids decay and the formation of humus. Soils that are limed need to have enough organic matter added to them to keep up the supply of humus, the decay of which is hastened.

Kinds of lime

The word "lime" as used by farmers may mean any one of the following compounds: (1) burnt lime or "quicklime," such as is used by plasterers; (2) water-slaked or "hydrated" lime, made by putting water on

quicklime; (3) ground limestone and air-slaked lime, the latter being made by letting quicklime or water-slaked lime stand exposed to the air for a long time. These all serve the same purposes when used on the land. Care must be taken not to put quicklime or hydrated lime on a crop, as they may burn it.

Gypsum

Gypsum, often called "land plaster," also contains calcium, along with sulfur. It has recently given remarkable results when applied to alfalfa land in the West. Perhaps the reason for this is that the land upon which it was used lacked sulfur.

The value of barnyard manure

Barnyard manure. There are many reasons why fertilizer that comes from stables and cattle corrals is more commonly used by farmers than any other. It is found on every farm and costs the farmer nothing but a little care and labor. In some respects it does the crop more good than do the mineral fertilizers of commerce. (Exp. 6.) In spite of the great value of manure to the soil and the small expense and trouble of making good use of it, many farmers still use it to fill holes about their land. Others who do put it on the fields allow much of it to go to waste. But farmers who understand its value use manure in such a way as to make it add both to the quantity and quality of their crops.

One man's success with crops; his method of using manure

A Pennsylvania dairyman, by good management, made his farm so productive that people came from great distances to study his methods. The Department of Agriculture had a bulletin prepared explaining the causes of this man's great success in growing crops. One of the most important of these was the way in which the barnyard fertilizer was used. Every morning it was hauled

International Harvester Co.

FIG. 138. A manure spreader in operation. The machine can be set to spread a fixed amount to the acre.

to the fields and spread (Fig. 138), thus preventing any of it from being wasted and, also, keeping the barns clean. To make sure that nothing was lost, a gutter at the back of the stalls was kept filled with an absorbent material (leaf mold). Thus the liquid fertilizer, containing a great amount of nitrogen, was saved to be hauled to the fields.

Applying manure to the fields at once

Frequently removing all manure from the stable and spreading it on the fields is the surest way to prevent loss. If it can be plowed in immediately, it does the land the greatest amount of good. If, however, it is not convenient to haul and spread the manure regularly, there are different ways in which it can be stored for several months without very great loss.

Storing manure; the Dutch method

The thrifty farmers of Holland preserve the good qualities of stable manure by using a deep stall, dug several feet below the surface of the ground. The

animals tread on the manure, which is mixed with clean straw used as bedding, and so pack it that air does not enter freely. Keeping the air out prevents chemical changes that would cause much of the strength to escape in the form of gases. The bottom of the stall is tamped or cemented to prevent leakage.

Keeping manure sheltered and wetting it

Another method of storing manure is to pile it in a heap under shelter, keeping it so wet that not much air can penetrate it. Care must be taken not to put on so much water that some of it will drain away, carrying off dissolved plant-food materials.

The effects of exposure to rain and air

Figure 139 shows a wasteful method of keeping manure that is all too common. The manure is thrown in a loose heap, not only unsheltered, but even under the drip of the eaves. A great deal of nitrogenous material, potash, and phosphate are thus sure to be dissolved from the manure and washed away by the rain (Fig. 140 and Exp. 7). Also, the manure being alternately wet and dry, the air acts on it chemically so as to cause quantities of nitrogen to escape as gas. This accounts for the

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FIG. 139. The manure in this heap loses most of its value through leaching, and the boards against which it is piled rot; flies breed in the manure, and mosquitoes breed in the pool.

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FIG. 140. In a covered barnyard like this, manure can be saved with little loss through leaching.

strong odor of ammonia gas (containing nitrogen) that is often to be noticed about stables. Sometimes the heat of the chemical action becomes so great that the manure becomes "fire-fanged"; that is, it turns white like ashes and is not of much more value than ashes.

Compost

A compost heap is a mixture of manure, soil, refuse such as weeds, and plants left in the garden after the crop is gathered (Fig. 141). Bean and pea vines are especially valuable, since they contain much nitrogen. Matter that might otherwise be wasted is deposited in the compost heap, and the bacteria turn it into material that is excellent for greenhouse work and for use in seed boxes.

Flies very commonly carry disease, and that is the

Screening manure from flies

main reason why we should do all that we can to keep them from increasing. (Exp. 9.) The chief breeding place of flies is the manure pile. (Exp. 8.) The eggs are laid there, and in a day or two hatch as tiny white larvæ (maggots), which form pupæ that soon turn into flies (Figs. 144, 145, 146, and 147). Removing the breeding places of flies is of more value than killing thousands of the insects. It is the only way to destroy flies effectively. It is a simple matter to keep stables clean and to have the manure heap covered and closely screened to keep the flies from laying their eggs there. Many careful farmers also screen their barns as they do their houses.

The money value of manure as plant food

Good average manure mixed with straw that has been used for bedding contains about seven pounds of phosphate fertilizer and about ten pounds each of nitrogen and potash to the ton. Now, the ordinary market value of phosphate and potash in commercial fertilizer is 5 cents a pound, and the price of nitrogen is about 15 cents a pound. On this basis the phosphate in one ton is worth 35 cents, the potash 50 cents, and the nitrogen $1.50. This would make the plant food in a ton of manure worth $2.35.

Other value; humus

We must remember, however, that manure has important uses in the soil besides supplying plant-food materials. It becomes changed into humus, making the soil more porous and spongelike, so that it receives and retains water better. It contains millions of bacteria that aid in preparing plant-food materials. It serves as food for the beneficial bacteria that are already in the soil.

W. T. Skilling

FIG. 141. Making a compost heap. The boy at the left is putting on dirt, the one at the right is adding manure, and the third is bringing refuse from the garden.

How long the effects of manure last

Manure has a very permanent good effect upon the soil. At the great English experiment station at Rothamstead a field was regularly manured each year for twenty years. Then for twenty years more no fertilizer was used. But in all this time the field did not entirely lose the good effects of the manure which had been used. It continued to yield a better crop than did a similar field that had never been fertilized.

Precautions in the use of manure; quantity

In using manure it should be remembered that too much will kill the crop instead of benefiting it. From two to eight tons to the acre is considered a good quantity for an ordinary field crop. Market gardeners sometimes use as much as forty or fifty tons to the acre. (This would be about two pounds to each square foot.)

Too much straw

If there is much coarse, dry straw with the manure, only a moderate amount should be put into the soil. A layer of straw a few inches under the surface will break the connection between the surface soil and the moist earth below, so that capillary action cannot bring water up to the roots of the crop.

Effect on dry land

In very dry climates fresh manure in large amounts may burn out the crop. The water which should nourish the plants is used in fermenting the fertilizer. Only manure that has already been rotted should be used where the soil is likely to become very dry.

The increased yield due to fertilizer

A 58-year test

The farmer will be well rewarded for his use of fertilizer. Experiments with and without fertilizer extending over a period of more than fifty years were made at the Rothamstead experiment station. The fertilizer used on one plot of wheat each year was barnyard manure. On a similar plot, wheat was raised without any fertilizer. The average annual yields of wheat in bushels for different periods were as follows:

	1844–51	1852–61	1862–71	1872–81	1882–91	1892–01
Plot not fertilized	17.2	15.9	14.5	10.4	12.6	12.3
Plot manured . .	28	34.2	37.5	28.7	38.2	39.2

The unfertilized plot, in the latest of these yields, showed a falling off of about one third from the first yield, while the plot receiving manure showed an increase in yield. Even from the start about twice as much wheat was produced with fertilizer as without, and after many years of cropping the fertilized field yielded three times as much as the other.

Why mixed farming is recommended

In order to assure himself of a supply of manure, every farmer should keep some livestock. If he does so he makes a double profit, — a profit on feeding the grain that he raises and a profit on the manure that is put back into the soil. Grain farming without keeping a reasonable number of farm animals is called "soil robbing"; the supply of humus and the other elements of fertility grows less; the soil becomes poorer, and so does the farmer. That is why those who best understand the science of agriculture recommend mixed farming — the raising of livestock along with properly rotated grain crops.

Experiments and Observations

1. Visit a fertilizer store and copy the labels on the bags showing the composition of the fertilizers. Bring these copies to class for discussion.

2. Plant two rows of radishes, sprinkling a little sodium nitrate or a little complete fertilizer in one row with the seeds. Avoid using too much fertilizer, as this would kill the plants.

3. Into a tablespoonful or more of dilute sulfuric acid pour household ammonia until the acid is neutralized and the mixture smells of ammonia. Boil away the water. A white solid will be left. This is sulfate of ammonia.

4. Soak wood ashes in a bucket for several days. Pour off the clear liquid and boil it away to get the dissolved potash.

5. Thoroughly dry two balls of wet clay, in one of which a little lime is mixed. Which one bakes the harder in the sun?

6. Test the beneficial effects of manure by raising the same kind of crop on each of two small garden plots. Fertilize only one of the plots, by digging manure into the soil.

7. Partly fill a box with manure and pour water over it occasionally. Catch the drippings in a bucket, and notice the color. Florists use such liquid fertilizer on ferns. What does this experiment show as to the effect of rain on unprotected manure heaps?

8. Examine a manure heap in warm weather for the eggs, larvæ, and pupæ of flies.

9. Make a cage flytrap of wire screen.

References

"Commercial Fertilizers." Farmers' Bulletin 44.
"The Liming of Soils." Farmers' Bulletin 921.
"Barnyard Manure." Farmers' Bulletin 192.
"House Flies." Farmers' Bulletin 851.

CHAPTER THIRTEEN

INSECT ENEMIES AND ALLIES

The locust is fierce, and strong, and grim,
And a mailed man is afraid of him:
He comes like a winged shape of dread,
With his shielded back and his armed head,
And his double wings for hasty flight,
And a keen, unwearying appetite.

MARY HOWITT

Kinds of insects

SCIENTISTS have named not far from half a million kinds (species) of insects, and they estimate that the list will be about four times as long as it now is, when all the different kinds in the world have been discovered. Their numbers are greater than the numbers of all other kinds of animal life together.

Why their numbers are enormous

Insects in the struggle for existence. There are several reasons why insects are able to keep alive in such enormous numbers. (1) They escape easily from enemies, such as birds, by reason of their small size, their power of flight, and their protective coloring which makes them hard to see. (2) They have a hard (chitinous) covering which protects them from injuries and from germs. (3) The change of form through which insects pass allows them to spend a good deal of their life in a protected place, as the caterpillar in the cocoon, or the codling moth, during its larval stage, within an apple. (4) They reproduce with enormous rapidity. The eggs hatch quickly and the young soon come to maturity, so that there may be many generations of some insects in a single season. The fly, for example, may lay as many as one hundred and twenty

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FIG. 142. Equipment for insect study: insects on cotton under glass; butterfly net; block for mounting; killing bottle (containing cyanide); insects mounted on pins in glass-covered frame.

eggs, which, within three weeks, pass through two intervening stages and become mature flies ready to lay more eggs.

How increase is checked

Insects are held in check through being destroyed by each other and by diseases that kill great numbers of them. If their increase were unhindered, they would destroy all the food that is needed by man and animals.

Harmful and beneficial insects

In their search for food insects may be either harmful or beneficial to man. If there were no insects, some crops would produce much larger harvests and some could not be grown at all. The harm done by chinch

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FIG. 143. For the study of insects as they live on a plant, a cage can readily be made of a covered lamp chimney or the top of a flytrap.

bugs, army worms, and grasshoppers is well known. On the other hand, it was found impossible to raise red clover in Australia, where it had been introduced from England, until the bumblebee, the clover's friend, was brought also. Smyrna fig trees never ripened a single specimen of their fruit in California until, after years of failure, a little insect was imported from Smyrna and turned loose in the orchards to carry pollen from tree to tree.

Metamorphosis

The life histories of insects. The higher animals are of much the same form from birth to old age, but insects pass through several changes during their lifetime (Figs.

Am. Mus. Nat. Hist.

FIGS. 144 and 145. Stages in the life of the common house fly or filthy fly: Fig. 144, eggs of fly. They hatch in about 12 hours. Fig. 145, larva of fly. The larvæ (maggots) retain this form for about 5 days, during which they are very active.

144, 145, 146, and 147). Some insects look as different in successive stages as if they were different animals. Thus the caterpillar becomes in time a chrysalis and after that a butterfly. Such change from one form into another is called " metamorphosis." (Exp. 1.)

Life history of the grasshopper; incomplete metamorphosis

Some insects change very little and are said to undergo incomplete metamorphosis. The grasshopper is such an insect. It comes from the egg looking so much like an adult grasshopper that no one would mistake it for any other insect. It has no wings, however. It eats hungrily at this time, and whenever its skin becomes too small for its growing body it molts, coming forth in a new and larger skin. Its wings begin to develop, and they become longer at each molt. Five times the skin is cast, splitting down the back and allowing the insect to crawl out. In its incomplete stage the insect is called a " nymph," to distinguish it from the full-grown adult. At the fifth molt the grasshopper emerges from its cast-off skin with a full-grown pair of wings.

When an egg of a butterfly hatches, we have no butterfly

Am. Mus. Nat. Hist.

FIG. 146. Pupa of fly. The resting stage lasts for about 5 days.

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FIG. 147. The adult fly. About 10 days after leaving the pupa case, the fly is ready to lay a batch of perhaps 120 eggs. (Figures 144 to 147 are from photographs of large models.)

The butterfly; complete metamorphosis

at all, but a caterpillar. There are many insects which in form resemble a worm, when they are first hatched from the egg. In this wormlike stage of life they are called "larvæ" (singular, "larva"). Many insects

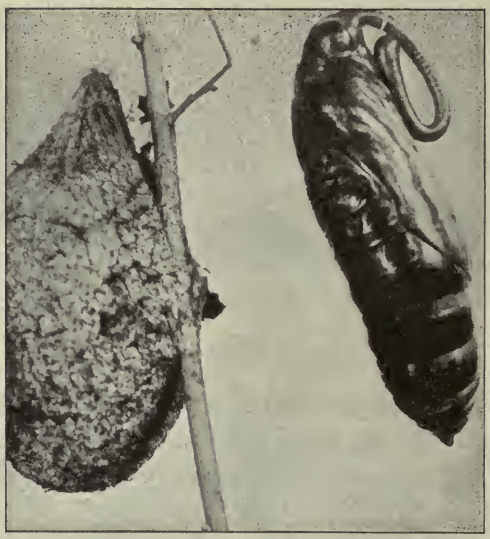

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FIG. 148. A silky pupa case (Cecropia moth) and a hard pupa case (Sphinx moth).

do practically all of their eating and growing while in the larval stage, and that is why the larger number of insects are more destructive then than at any other time.

The pupa

After a caterpillar has grown to its full size, it becomes a pupa and remains at rest for some time — perhaps over winter — protected often by a silky cocoon which it has woven about itself (Fig. 148). The insect in the resting stage is called a "pupa." Although motionless, or nearly so, its life is not at a standstill. A wonderful change is taking place, so that when the covering is broken open a full-grown butterfly or moth emerges, ready to lay more eggs to start again this series of changes. Thus, in such insects as the butterfly, where at each

A change during rest

metamorphosis there is a complete change, we have four stages: first the egg, then the larva, then the pupa, and after that the adult insect. Where the changes are not so great, as in the grasshopper, we have three stages: the egg, the nymph, and the adult.

The number of stages of insect life

Sprays for killing insects. When we have learned how different insects feed, we can more intelligently set about to destroy them. For example, there are many pests that live on the inner juices of plants by thrusting their beaks through the surface and sucking out the food. It would plainly be labor lost to try to kill these insects by spraying a stomach poison on the leaves. Not being able to poison their food, we must use what is called a "contact poison," that is, something like kerosene, which, coming in contact with the outside of the body, will kill the insect (Fig. 149).

Feeding habits of insects

Insects like potato bugs and cutworms, on the other hand, feed directly upon the leaves or other parts of plants, biting off pieces and swallowing them. Spraying arsenical poison upon the surface that is attacked is therefore an effective remedy for biting insects.

Sucking and biting insects

F. E. Lutz, Am. Mus. Nat. Hist.

FIG. 149. Sucking insects. Aphids (plant lice) that cause curl leaf in currants (enlarged). These aphids work on the under surfaces of the leaves. Kerosene emulsion, to reach them, should be applied before the leaves become much curled. The two-spotted ladybird is the great enemy of this pest.

Sprays for sucking insects; external poisons

Many of the sucking insects have softer bodies than the biting insects usually have, which makes it the easier to kill them with contact poisons. This is especially true of the many kinds of plant lice. The sprays used for such insects may be either of a kind that will kill by poisoning through the soft skin of the insect, or by shutting up the breathing pores (spiracles). Tobacco extract will kill by poisoning through the skin. A mixture containing kerosene (kerosene emulsion) will close the breathing pores (Fig. 150).

Kerosene emulsion

Oil will not dissolve in water, but if oil and water are shaken up together the oil breaks into very fine drops which remain for a little while floating all through the water. Such a mixture of oil and water is called an "emulsion." If a little dissolved soap is added, the emulsion will be much more perfect and the oil and water will not separate so readily. A good recipe for making kerosene emulsion is as follows: Dissolve a one-inch cube of laundry soap in a pint of hot water. Remove from fire and add one pint of kerosene. Churn with egg beater. For trees or plants in foliage dilute this mixture with three gallons of water. For dormant trees without leaves dilute with only one gallon of water. (Exp. 2.) Such a spray is used for killing plant lice and scale insects. Just before being used it should be thoroughly mixed by putting the nozzle of the spray pump into the bucket or barrel and pumping the mixture through until it is creamy.

Recipe

Soap-powder spray

A simple spray that will kill scale insects is made by dissolving one pound of soap powder in five gallons of water. This solution should not be used on tender plants, as it may burn the foliage.

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FIG. 150. Using a compressed-air type of sprayer. Notice the upward turn of the nozzle for underspraying. Air is compressed in the tank by means of a pump, as it is in an automobile tire.

Tobacco extract

The most effective spray for plant lice is tobacco extract. It may be purchased as a very concentrated liquid, to be diluted according to directions on the bottle, or it may be made by soaking tobacco stems in a bucket of water. Tobacco spray spreads over the leaves better if a little soap is dissolved in it.

The biting insects are usually killed with a stomach poison made of some compound of arsenic. Paris green

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FIG. 151. Apples ready to spray for codling worm (left); too late to spray (right).

Sprays for biting insects; internal poisons

Lead arsenate

has long been used for this, but because it is hard on tender plants another arsenical compound called "lead arsenate" is now more commonly used. Lead arsenate sticks to the leaf better than Paris green does, and as it is white one can tell more easily when the plants are well covered with it. Lead arsenate is sold either as a paste or a dry powder. Either form can be used in a water spray, or the powder may be dusted on the plants. The dry powder sticks better if it is used when the dew is on the leaves.

The importance of spraying at the right time

The time when an insect can be reached and affected most easily is the best time for spraying. The case of the codling moth of the apple illustrates this. The moth lays its eggs a few weeks after the trees have begun to bloom. The eggs hatch into tiny larvæ, and these usually crawl to the blossom ends and begin gnawing

their way into the fruit. If the tree is sprayed with lead arsenate after the petals fall and before the calyx cup closes (Fig. 151), the larvæ are killed. But if the spraying is not done before the calyx closes, as it does very soon, the poison does no good. In the case of scale we have another example showing how necessary it is to choose the right time for spraying. Scale insects are soft-bodied. They crawl about for a few days when first hatched and then settle down in one spot, where the female insects cover themselves with a scaly coating which protects them. The time to spray for scale is evidently when a new brood hatches.

When to spray for codling moth; scale

Fumigation. A method of killing insects that is more certain than spraying is fumigation. This consists in producing a poisonous gas (usually cyanide gas) under a tree and letting it rise among the branches. To keep the gas from escaping, a tent is placed over the tree, and the gas is generated under it. The gas is held in for about an hour (Fig. 152). Cyanide and its gas are very deadly. Extreme care must be taken to avoid inhaling any of the gas.

Using cyanide gas

Caution

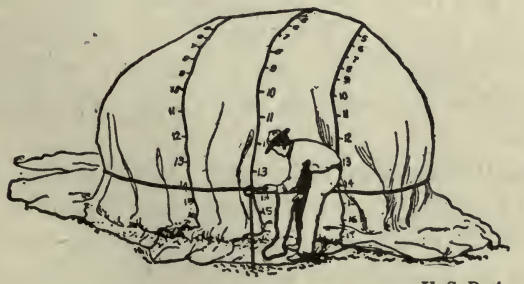

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FIG. 152 A tent properly adjusted over a tree that is to be fumigated.

Carbon bisulfid

Another fumigating material used for killing certain insects is carbon bisulfid. This is a liquid which evaporates even more rapidly than gasoline. Worms that burrow in the ground and attack the roots can be destroyed in loose, sandy soil by pouring the carbon bisulfid into holes made with sharp sticks. Care must be taken to punch the holes at safe distances from the roots of plants. The holes are closed so that the gas will permeate the soil. Carbon bisulfid is also used to fumigate nursery stock that can be placed in an air-tight box or room. A dish containing sufficient liquid to fill the inclosed space with gas is set in the upper part of the box or room. As the liquid evaporates, the gas, which is very heavy, sinks and floods the inclosure.

Fumigating the soil and cleaning nursery stock

Killing grain weevils

Beans and peas and grain in storehouses are often infested with weevils, which gnaw their way into the seed and eat the inside, leaving nothing but the hull (Fig. 153). These weevils are easily killed in a storehouse or in a tight box by fumigating with carbon bisulfid. Grain elevators and mills are regularly fumigated with cyanide gas. Moths in a trunk or tight closet can be got rid of by fumigating with carbon bisulfid.

Caution

This gas, though suffocating, is not so poisonous as cyanide, though it may cause headaches; and the liquid, like gasoline, is dangerous near a fire. The gas from it is explosive.

Predacious insects

Natural destroyers of insects. In spite of all that we can do to destroy harmful insects, we still need the assistance of their natural enemies. Every form of animal life has its enemies that hold it in check, and the most effective enemies of many harmful insects are other

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FIG. 153. Beans that have been weevil-eaten. Weevils are destructive both in the larval and in the adult stage

insects that feed upon them. The latter are called "predacious insects."

How the cottony-cushion scale was checked

The way in which insects multiply if freed from their natural enemies was shown some years ago when the cottony-cushion scale was introduced from Australia into California. In its native country it had not been a very serious pest, but here it did millions of dollars' worth of damage and threatened to destroy entirely the citrus trees and a number of other kinds of trees. Search was made for an insect that would destroy this pest, and in Australia was found a beetle known as the "Australian ladybird," which devoured the cottony-cushion scale in that country (Figs. 154, 155, 156, and 157). A few of these ladybird beetles were brought to America and

turned loose in the orchards. They multiplied rapidly, and soon the ravages of the cottony-cushion scale were checked. Now if that pest is seen to be increasing in any locality, ladybird beetles are brought from the state insectary (where beneficial insects are reared for the public), and they quickly control the pest.

Ladybird beetles

There are known to be two thousand kinds (species) of ladybird beetles, most of which, both as larvæ and adults, live on other insects (are carnivorous) and are helpful to men. Only two of the kinds that are known in the United States, the squash ladybird and the bean ladybird, are plant eaters (herbivorous) and therefore pests. Plant lice, which do so much damage, form the chief diet of one ladybug. Thousands of pounds of these insects are annually collected in the mountains where they breed and are sent to districts in which they are needed for the control of plant lice.

Spiders

Spiders are of very great service in holding insects in check. Strictly speaking, the spiders should not be classed as insects: a true insect has three pairs of legs; a spider has four.

Parasitic insects

There is another class of insects called "parasites," many of which destroy pests, not by devouring them, but by attacking them from within. The insect attacked is known as the "host." Most commonly a parasite lays its eggs in the body of an insect, piercing the skin with a sharp egg-laying device called an "ovipositor." Then, when the eggs hatch, the grubs (larvæ) feed upon the body of the host, killing it. Sometimes a small insect parasite pierces the eggs of a larger insect with its ovipositor and lays its own tiny eggs within.

How some of them work

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FIGS. 154 to 157. A biting insect: the Australian ladybird beetle at different stages (much enlarged). Fig. 154, larvæ (lower left corner); Fig. 155, pupa (upper left corner); Fig. 156, adult (upper center); Fig. 157, larvæ and adults attacking cottony-cushion scale (right).

The fate of many caterpillars

Of course the larger eggs never hatch, but instead furnish food for the tiny grubs which develop within them. Most parasites attack caterpillars or other larvæ, rather than eggs or adult insects (Fig. 158). Often a caterpillar that is attacked does not die in the larval stage, but succeeds in forming a chrysalis. The butterfly, however, never emerges, but a whole swarm of some very different insect comes forth.

External parasites

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FIG. 158. A parasitic insect laid its eggs within the body of this caterpillar. When the eggs hatched, the grubs bored their way through the skin of the caterpillar and formed pupæ.

Insect parasites on the larger animals. There are many parasites that infest larger animals instead of living upon other insects. Some of these live within the host, but others stay on the skin and suck the blood of the host. Examples of the latter are the tick, the flea, the louse, and the mosquito.

The Texas-fever tick

External parasites are not only very annoying to animals, but some of them do an immense amount of damage. The Texas-fever tick, found upon cattle in Mexico and along the southern border of the United States, causes a fever from which many cattle die. To free the cattle from it, they are dipped in a poisonous solution contained in a large tank through which the cattle are driven (Fig. 159). To prevent Mexican cattle from bringing the insect across the line into California, our government has built a barbed-wire fence along the border between the two countries, beginning at the Pacific Ocean and

extending about a hundred miles inland to the desert (Fig. 160).

The scab mite in sheep

Sheep as well as cattle suffer from parasites, the one most harmful to sheep being a very small mite that produces a disease called "scab." Thousands of sheep lose their wool before shearing time on account of scab. Dipping in a tank of tobacco extract and sulfur (or lime-sulfur) is the remedy for this trouble.

U. S. D. A.

FIG. 159. A dipping tank made of concrete. Here sheep are being dipped to kill the mite that causes scab.

The screw worm

One of the pests that causes a great deal of trouble for stockmen is the fly that lays its eggs in the open sores of animals, causing screw worms. All kinds of animals should be carefully watched, and any hurts should be covered with tar to keep flies away. If maggots get into a sore, they can be killed with chloroform.

Carriers of disease

The flea sometimes becomes a source of danger to mankind. It is the carrier of an Asiatic disease called "bubonic plague." Fleas that have bitten a person having this disease are capable of giving it not only to another person, but to rats. Since the fleas may pass from

Louis Harvey

FIG. 160. Building a fence along the border to keep out Mexican cattle, which are often infected with fever ticks.

rats to men, human beings are in danger wherever there are any infected rats (Fig. 161). A few years ago the city of San Francisco spent many thousands of dollars in destroying rats among which the plague had spread.

Mosquitoes and malaria

The mosquito may be regarded as a parasite, for it secures its living in part, at least, by sucking the blood of animals, while the juices of plants also furnish it with food. The male mosquito has not a beak strong enough to pierce the skin of an animal, and he must rely upon plants for all his food. Many kinds of mosquitoes are quite harmless, except that they take a drop of our blood now and then. But one kind was the carrier of yellow fever until that disease and the mosquito that kept it going were practically stamped out together. Another kind, the Anopheles, is the carrier of malaria. If an Anopheles mosquito bites a person suffering from malaria, it draws the disease germs into its own body.

These germs develop in the mosquito and are thrust into the blood of every person that the mosquito may thereafter bite.

Destroying mosquitoes

There are two ways to prevent the spread of malaria: one by screening to keep the mosquitoes from biting persons and so carrying the disease; the other by destroying the mosquitoes. Draining swamps and pools deprives mosquitoes of their breeding places, and covering all stagnant water with kerosene kills the larvæ that may already be in the water. The " wigglers " cannot breathe if there is a film of oil over the water. Mosquitoes do not fly very far; consequently, if every one would see to it that no stagnant water was allowed to stand in his neighborhood, or that water that could not be drained was covered with oil, malaria would not be so common.

Elmer S. Green

FIG. 161. A rat catcher at work in Colombo. The governments of Ceylon and India carry on a ceaseless campaign of destruction against rats, and they find that it pays.

Army worms

Plant-eating insects. Army worms are the larvæ of a night-flying moth. They are sometimes very destructive, and, again, for many years it may be difficult to find any trace of them. There are seasons when they travel in great numbers from one field to another, devouring the crops as they go. It is possible sometimes to protect a field against them by plowing a deep furrow around it. If the sides are steep and the dirt loose and crumbly, the worms after crawling into it cannot well get out.

Checking their progress

Cutworms

When army worms are not numerous, they are sometimes spoken of as " cutworms." But the real cutworm is the larva of a different moth. Cutworms feed only at night and hide in the ground during the day. There are two ways of trapping them in a garden. One is to lay leafy boughs around in the garden so that the worms will crawl under these for shelter. The other way is to punch holes in the ground with a hoe handle. In the morning several worms may be found in each hole. Arsenate of lead sprayed upon the leaves is a good protection against cutworms. They can also be killed by a poisoned bait, made of a pound of Paris green mixed with forty pounds of bran. This is sweetened with molasses, and enough water is added to make a stiff mass. Birds can be prevented from getting this poison by putting it under boards, which are held up from the ground far enough for the worms to crawl under.

Remedies

Tent caterpillars

A most interesting as well as destructive insect is the tent caterpillar. It is especially harmful to the apple tree, but it also attacks the cherry, plum, peach, and several other trees. It feeds upon the leaf, each cater-

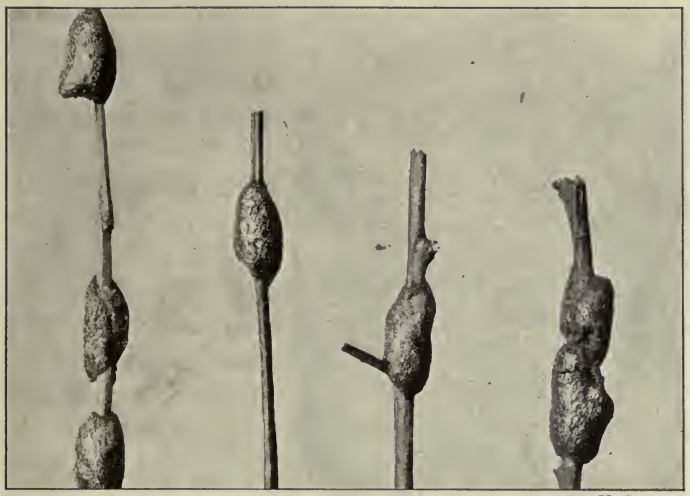

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FIG. 162. Egg masses of the apple-tree tent caterpillar. Twigs bearing them are easily distinguished in winter, and they should then be clipped off and burned.

How they live

pillar eating one or two leaves daily. The peculiar and interesting thing about these caterpillars is that instead of living independently of one another they live in colonies, as ants and bees do. To shelter the colony, they build a tent which resembles a spider's web among the branches. The mother moth lays a cluster of about one hundred and fifty eggs on a twig (Fig. 162). The larvæ hatched from such a cluster remain together as a colony and build the silky tent into which they go for protection (Fig. 163).

Remedies

Like other biting insects tent caterpillars can be killed by spraying the trees with arsenical poison. But two other methods are used: one is to destroy the colonies

U. S. D. A.

FIG. 163. Nest and larvæ of apple-tree tent caterpillar in fork of wild cherry. There are a number of kinds of tent caterpillars, but this one is the commonest and the most destructive.

Two imported pests

in their webs, and the other is to search for the egg masses in winter when the trees are bare. The pupils of one school in Massachusetts undertook the work of protecting the apple trees in the neighborhood. They went through the orchards in winter time and picked off the twigs on which there were egg masses. This saved the fruit of the following summer.

The gypsy moth and the brown-tail moth may be spoken of together, for they are similar in some respects. Both were introduced into the New England States from Europe and both destroy the foliage of fruit and forest trees. A naturalist brought the gypsy moth from France. Some of them escaped from him, and within twenty years they had so multiplied that they were killing all the trees in localities where they were especially numerous. Some-

thing like a million dollars is spent annually in an effort to destroy them, or at least to keep them from spreading.

The peach-tree borer

Many peach trees throughout the whole country are killed by a larva that bores into the lower part of the trunk and the crown of the roots. It works in the growing wood just under the bark. To prevent the wasplike mother moth from laying her eggs on the lower part of the tree, the trunk can be wrapped with heavy paper and the roots banked up with earth during the egg-laying season. Or, better than banking with earth, a coating of "Grade D" asphaltum may be melted and applied to the trunk from a point five or six inches below the ground to the same distance above the ground. The covering may not prevent all worms from entering the tree. Those that succeed in boring into the bark must be dug out with a knife.

The cotton-boll weevil

A very destructive insect known as the "cotton-boll weevil" came across the Rio Grande from Mexico into Texas about 1890, and each year since that time it has spread over a larger area. Its only food is the cotton plant. It works mostly in the unopened blossoms or "squares"; but during the latter part of the season, when blossoms are scarce, it works also in young bolls. Two methods of control are early planting, and burning the

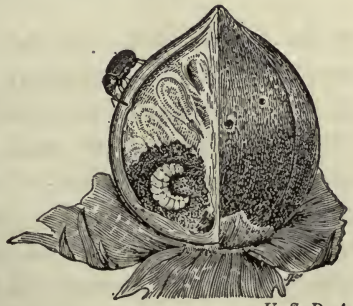

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FIG. 164. The cotton-boll weevil. Larva and adult at work.

Methods of control

U. S. D. A.

FIG. 165. A common garden slug. Several troublesome kinds of slugs have been brought to this country from Europe.

stalks in the fall. If the cotton stalks are burned by the middle of October, a very large percentage of the eggs, larvæ, and full-grown weevils will be destroyed. Plowing the stalks under serves the purpose about as well, and this is better for the soil, but it is difficult to do when the cotton is large. The earlier cotton can be brought to maturity the safer it is, for the boll weevils increase in number as the season advances (Fig. 164).

Mollusks

Snails and slugs (Fig. 165), though not insects, eat

plants much as the biting insects do, and they can be killed with a poison spray. Plants may also be protected from them by a line of powdered lime such as is used to mark a tennis court; they cannot go through it. Salt sprinkled on a slug will cause it to shrivel and die almost instantly.

The earthworm

Though the earthworm resembles the larvæ of some insects, it is a very different creature. Like some of the insects, it is an ally of the farmer. It improves the soil. The scientist Darwin calls it "the great plowman of the world." In making its way through the soil, it swallows earth, which it ejects at the surface. The passageways that it makes allow air to enter the soil more freely and aid drainage. The earthworm lives partly on organic matter that is mixed with the earth that it swallows. At night it comes to the surface and feeds on very small fragments of leaves and stems. It finds these near the mouth of its burrow, in which it keeps its tail anchored while feeding. If it left its burrow completely, it might never find its way back, for it is unable to see.

How it improves the soil.

The ways of bees

Honey bees. One of the insects most worthy of study, both on account of its interesting habits and its usefulness to man, is the honey bee. If people realized how simple a thing it is to care for bees and how profitable they are, the family beehive might become as common as the family cow. But bees are important not only as producers of honey; as carriers of pollen they cause the fertilization of many flowers, and some plants depend on them alone for this service.

To study the habits of bees an "observation hive,"

W. T. Skilling

FIG. 166. Studying bees at school. When swarming takes place, the new colonies are disposed of to pupils.

How bees multiply

made with glass sides, is very convenient (Fig. 166). The long-bodied queen may be seen within a circle of workers, their heads all turned toward her. The tiny white eggs which she lays may be seen at the bottom of the cells in the comb. In three days these hatch into tiny white larvæ, which are carefully fed by the "nurse bees." The larvæ grow so fast that in five or six days each of them nearly fills his cell, which is then sealed over by the bees. Without receiving anything further from the bees in the hive except warmth, the young, now called pupæ (singular, "pupa"), change into fully developed bees. This takes twelve or thirteen days more. Each new bee now eats the capping from its cell and emerges, to begin doing its part in the work of

the colony. The whole time required for the development from egg to adult is twenty-one days for a worker, twenty-four days for a drone (male bee), and but sixteen days for a queen (Fig. 167).

The work of a colony

Within the hive there are many different duties to be performed. Nurse bees must care for the larvæ. In hot weather some of the bees fan with their wings for ventilation. If it is cold the bees all cluster in a compact ball in one part of the hive, and by vigorous muscular exercise of legs, wings, and abdomens, keep themselves warm. They are thus able to raise the temperature within the hive many degrees above that of the outside air.

Materials that bees use

Honey is made from the nectar of flowers, which is taken into the "honey stomach" and rapidly changed from nectar to honey during the homeward flight. Wax for the comb exudes from the body of the bee while it stands at rest in the hive, somewhat as perspiration exudes from one's skin, or saliva from the glands of the mouth. The cement, called "propolis," with which the bee seals up cracks in the hive, is gum gathered mostly from the buds of trees.

A. I. Root Co

FIG. 167. A drone, a queen, and a worker bee (left to right).

W. T. Skilling

FIG. 168. His first hive. One such colony should yield enough honey for the family, and the boy, if a Scout, can earn a merit badge in learning to care for it.

Bee keeping

Making a start with bees is as simple a matter as making a start with poultry (Fig. 168). A hive is no more expensive than a chicken coop, and a colony of bees to put into it may be purchased from a dealer in bee materials if not from a bee keeper of the neighborhood. A hive may very easily be made at home. The inside dimensions of one of the standard hives are: width, $13\frac{1}{4}$ inches; length, $18\frac{1}{4}$ inches; and depth, 10 inches. The dimensions should in any case be such that the hive will fit the pound frames which are purchased from a dealer in supplies.

The hive

How to get straight comb

In order to induce the bees to build a separate comb in each of the nine or ten frames placed in a hive, it is necessary to put some starter in each frame. The

"starter" or "foundation" is made of beeswax that has been stamped out into sheets about as thick as paper. A sheet is fastened in each frame where the comb is to go, and the bees build upon it. Without foundation the combs may run in any direction in the hive and the frames cannot be lifted out separately.

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FIG. 169. A wire-gauze bee veil gives perfect protection. A cloth veil may touch the face and allow bees to sting through it.

After the bees have filled the hive with comb and honey and "brood" (young bees), a second story, called a "super," is added, and in this the bees will store their surplus honey. The queen, which lays all the eggs, seldom goes up into the super; so it is likely to contain honey only, and no brood. It is from the super that the beekeeper gets his share of the honey, but he should leave a sufficient amount, about fifteen pounds all together, for the bees to live on during the winter (Fig. 170).

The surplus honey

In the spring bees are apt to swarm. That is, the colony divides, one part remaining in the hive with a newly hatched queen, and the rest, accompanied by the old queen, flying out to find a new home. The swarm usually alights in some tree or bush that is near and

Swarming

W. T. Skilling

FIG. 170. A young beekeeper. He is wearing a wire-gauze veil and long gloves. The frame that he holds above the hive contains sealed brood and honey. On the hive hangs a smoker, and just to the right is a super filled with pound frames. On top of the super is a chisel for prying frames apart, and beside the chisel stands a pound frame, in the top half of which a strip of foundation has been put in place. At the extreme right is a super to hold the two large frames leaning against it. One of these frames shows foundation all the way across; the other shows foundation only halfway across.

clusters. Here the bees remain for a day or two while a few, acting as scouts, go out in search of a permanent home. When a suitable place is found, perhaps in a hollow tree or an unused chimney, the swarm follows the scouts to it, and housekeeping is again set up. While the bees are resting in a cluster, it is an easy matter to capture the swarm. One needs only to put an empty hive close up under the cluster and shake the bees into it. They generally are content in the hive, especially if it contains some honeycomb.

Capturing a swarm

The bee's sting has made it unpopular, but the sting is seldom used unless the hive is opened or disturbed in some way. Opening the hive and handling the bees

How to keep safe

can be made perfectly safe by wearing a veil and a pair of canvas gloves with an extension to reach halfway up the arms, as shown in Figure 170. An elastic band placed above the top of each glove keeps the bees out.

Races of bees

Most of the bees in this country are either the wild black bees or the golden-banded Italian bees. The latter are considered by far the better, as they are less liable to become diseased and are also gentler than the black bees.

Experiments and Observations

1. Collect eggs, larvæ, pupæ, and adults of as many insects as you can. Watch the changes from one form to another. Feed insects with the leaves on which they are found.

2. Make an emulsion of kerosene and soap and water. Spray it or wash it upon plants infested with scale insects or plant lice.

3. Using a hand lens, or a better microscope, examine small insects and insect eggs.

4. Note all the differences you can between an earthworm and the larvæ of some insect. Watch the earthworm crawl.

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CHAPTER FOURTEEN

THE FARMER'S FEATHERED HELPERS

Think of your woods and orchards without birds . . .
They are the winged wardens of your farms,
Who from the cornfields drive the insidious foe,
And from your harvests keep a hundred harms.

HENRY WADSWORTH LONGFELLOW

WILD birds are often annoying to the farmer, and he is sometimes tempted to think of them as his enemies and to treat them as such without stopping to inquire whether or not the good they do him may not be far greater than the harm. Our human friends often annoy us, but we do not want to do without them. Even the crow which pulls up newly planted corn in spring will later destroy numberless grubs, cutworms, and field mice, thus protecting the crop from its enemies. It is troublesome for perhaps a month at planting time, but during the other eleven months it does much to redeem its character.

Beneficial and harmful birds

We cannot say of any bird that it is altogether harmful or altogether beneficial. We can only put into one class birds that are more beneficial than harmful and into another class those that do more harm than good. The first class, which may be called beneficial, contains nearly all our common birds. Few birds should be classed as enemies.

The useful birds. The government has a department called the " Bureau of Biological Survey " which makes a business of finding out the habits of birds and animals.

Finley and Bohlman

FIG. 171. A black-throated gray warbler feeding its young. Small birds rear their young almost entirely on insect food.

The investigations of this bureau have thrown much light upon the problem of the value of birds. Around the nest of a pair of barn owls was found nearly a bushel of the remains of pocket gophers, which are so destructive to the roots of trees and field crops in some parts of the country. In another barn-owl retreat were found three thousand skulls of rats, mice, gophers, and other small animals (Fig. 172). The stomach of a Swainson's hawk contained a hundred grasshoppers, and as birds digest their food very quickly these must all have been eaten within a few hours. The lawmakers of Pennsylvania once, in ignorance, placed a bounty on the heads of hawks and owls (Figs. 173 and 174). In a year and a half, on account of the increase of field mice and other pests, it was estimated that the state had suffered a loss of four million dollars. The laws now protect these birds of prey, for it has been discovered that, although they may occasionally catch a chicken or a song bird, their food in the main consists of animal pests.

The value of owls and hawks

W. T. Skilling

FIG. 172. A young barn owl (also called monkey-faced owl). Remains of gophers, mice, a young rabbit, and a kangaroo rat were found about its nest.

Insect eaters

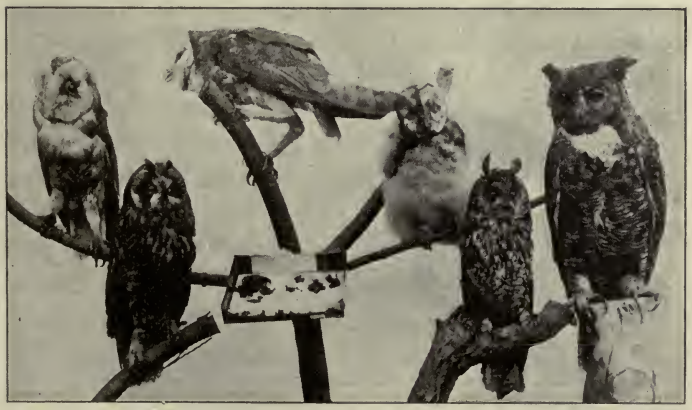
A killdeer's stomach was found to contain three hundred mosquito larvæ. A flicker had eaten twenty-eight white grubs. A nighthawk's appetite had called for three hundred and forty grasshoppers, fifty-two bugs, three beetles, two wasps, and a spider. Two pine siskins whose crops were examined had been content with no less than three hundred plant lice and nineteen hundred black scale insects.

Destroyers of weed seeds

Not only do the insect-eating birds and the birds of prey that destroy small animals benefit the farmer, but

W. T. Skilling

FIG. 173. Hawks: goshawk; red-tailed hawk; sharp-shinned hawk; marsh hawk (left to right). The goshawk, the sharp-shinned hawk, and the Cooper's hawk (Fig. 183) are among the very few birds that probably do more harm than good.



W. T. Skilling

FIG. 174. Owls: adults and young of barn owl (on the same branch); short-eared owl (at lower left of picture); long-eared owl and great horned owl (at right). In the tray are preserved the contents of the stomach of the barn owl mounted at the top of the branch.

San Diego Society Nat. Hist.

FIG. 175. A pocket gopher; a destructive burrowing animal that is held in check by owls.

the birds that live on seeds help him to keep his farm free from weeds. The crop of a pheasant was found to contain eight thousand chickweed seeds and a dandelion head. The sparrows (Fig. 177), of which there are so many kinds, are especially useful in destroying weed seeds. These little birds may often be seen clinging to a tall weed, picking at the ripening seeds. It has been estimated that each sparrow eats as much as a fourth of an ounce of seed a day, and that in one year all of the sparrows in a state like Iowa must eat about eight hundred and seventy-five tons of seed which might otherwise make a troublesome crop of

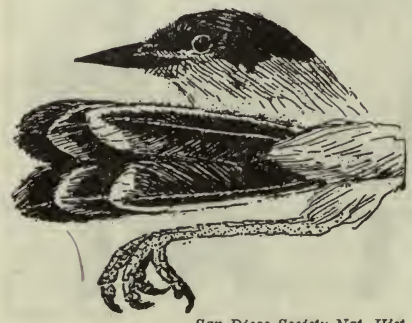


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FIG. 176. Head, tail (under side), and foot of gnatcatcher; a good example of an insect-eating bird.

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FIG. 177. Head of intermediate sparrow (left), and head of its young. This is a typical seed-eating bird. Notice the thick bill.

weeds. The English sparrow, however, is so destructive to grain fields that it is considered unfortunate that it was ever introduced into this country.

Insects held in check by birds

It is thought by some scientists that it would be impossible to raise crops without the help of birds that destroy harmful insects. Most birds eat insects, and even those that care least for them often feed them to their young, for young birds require food of this kind. From daylight till dark the parent birds are on the alert to capture worms and bugs.

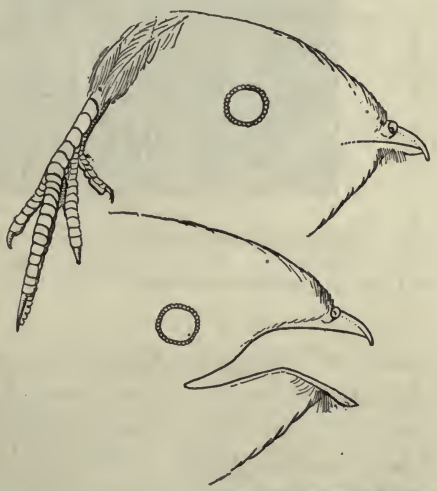

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FIG. 178. Head and foot of nighthawk. The mouth is adapted to catching insects on the wing. The foot is poorly adapted to perching.

Am. Mus. Nat. Hist.

FIG. 179. A red-winged blackbird (male). It feeds mostly on weed seeds and harmful insects. With the draining of the marshes in which it breeds, this bird is becoming less common.

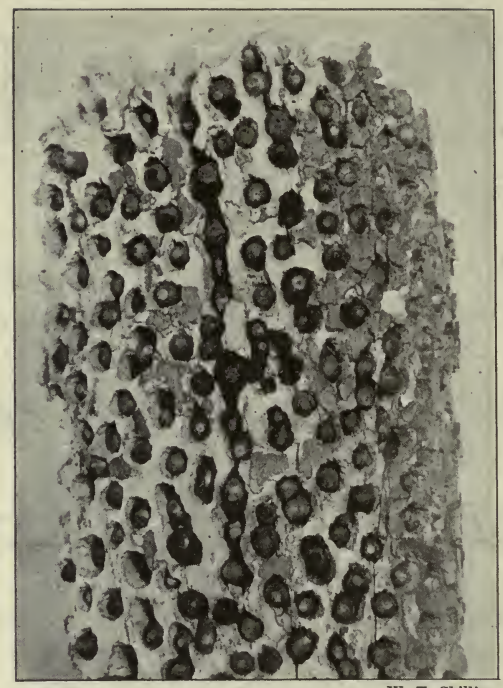
One pair of wrens are reported to have taken more than six hundred insects to their young in a day, and a pair of grosbeaks fed eight hundred insects to their growing family within eleven hours. The robin often brings condemnation upon itself by destroying fruit in the orchard; but by devouring insects, especially when nesting, it does very much to make up for any loss it

HELP WILD LIFE
TO DO ITS BIT
BIRDS MAKE AGRICULTURE POSSIBLE
By Killing Insect and Rodent Pests, They Save Crops Worth Millions of Dollars
FISH AND GAME FURNISH FOOD
THOUSANDS OF TONS ARE TAKEN ANNUALLY
Conservation Laws are designed to make Fish, Game and Birds more abundant and are vitally necessary for National Welfare
THE MAN WHO ILLEGALLY TAKES GAME OR FISH OR KILLS BIRDS DECREASES FOOD RESOURCES AND DEFRAUDS HIS COUNTRY
REPORT VIOLATIONS TO THE NEAREST GAME PROTECTOR
CONSERVATION COMMISSION, ALBANY

FIG. 180. Copies of this poster were displayed throughout New York by order of the State Conservation Commission.

The keen appetite of birds

causes. A single young robin ate one hundred and sixty-five cutworms in a day — nearly twice its own weight of them. Another ate from fifty to seventy-five worms daily for fifteen days. The enormous appetite of birds is accounted for by the fact that they



W. T. Skilling

FIG. 181. Acorns stored by a woodpecker in holes drilled in dead wood. Only one species does this — the California woodpecker.

have great power of digestion, disposing of a meal in about half the time that is required by other animals. It is because of their voracious appetites that birds are able to free our orchards, gardens, and fields from insect pests (Fig. 180).

To every bird its work

There is such a variety of birds, each kind finding its food in a little different way, that much more good is accomplished than could be done by one kind, however

Birds that feed in flight; on tree trunks; among the branches

numerous. The swallows, swifts, and nighthawks (Fig. 178) are particularly well fitted to capture insects flying in the open air. Their quick motion, rapid, darting flight, and wide, gaping mouth give them success in the air. The woodpecker, with his chisel-like beak, powerful neck muscles, grasping claws for holding to the bark of a tree, and stiff tail feathers, which help to brace him in position for work, is well equipped for destroying the boring insect foes of trees (Fig. 181). The little wren creeps about in hidden holes and crevices where insects would be overlooked by other birds. The brown creeper (Fig. 182), scrambling over the trunks and branches of trees, can see and capture tiny insects and eggs that would not be noticed by a less careful and observing bird. The oriole works among the branches of trees, the meadow lark works on the

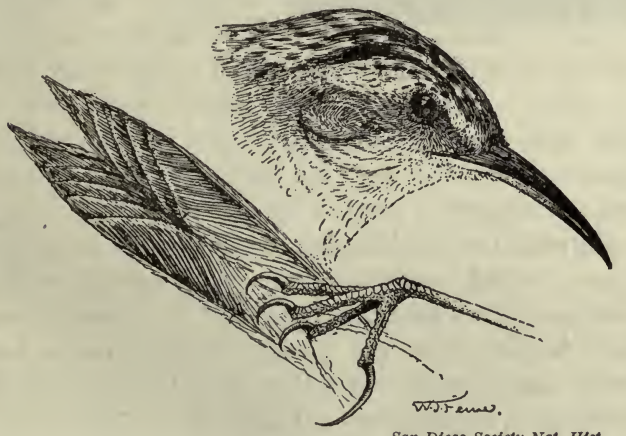


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FIG. 182. Head, tail (under side), and foot of the Western creeper. The creepers hunt their food in places that other birds cannot well explore.

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FIG. 183. A Cooper's hawk and its prey.

ground, the owl searches for rodents at night, and the hawk catches similar prey in daylight.

Bats

Bats, of course, are not to be classed with birds; but it is well to keep in mind that these curious little animals are very useful as destroyers of night-flying insects, which constitute the food of most of them.

We have considered the value of birds in an economic way: they help to save our crops and so have an actual money value to us. But, aside from this, the world would be a much duller place to live in if it were not for the song and the color and the interesting ways of birds.

Three hawks of bad character

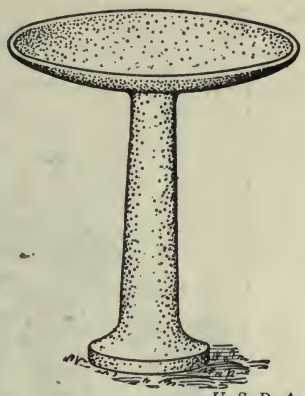
Harmful birds. Although birds have to their credit so much of good, still there are some few which do so much more harm than good that they must be classed as harmful. Among these are three members of the hawk family, the Cooper's hawk (Fig. 183), the sharp-shinned hawk, and the goshawk. These are so destructive to other birds and to young chickens that the laws do not protect them. The English sparrow, as mentioned

before, is a decided nuisance. The blue jay, also, is a bird with few friends, on account of his destructive, thieving habits. The eggs and young of other birds are not safe in his presence.

The English sparrow and the blue jay

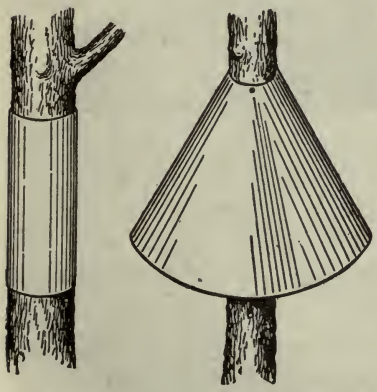
Protection of birds. Birds often have to go far for water, which they require more frequently than do many animals. They delight in a shallow pool or a dish of water (Fig. 184) where they may bathe and drink. We can do a great deal to benefit these creatures that help us so much, by placing water where they can reach it conveniently and with safety—especially from cats (Figs. 185 and 186).

Helping birds



U. S. D. A.

FIG. 184. A bird bath made of concrete. Such a bath is much safer for birds than is one that is placed on the ground within reach of cats.



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FIGS. 185 and 186. A sheet of metal fastened about a tree in either of the ways shown makes an effective guard against the climbing enemies of birds. Ready-made wire guards also are effective. No device of this kind should be fastened in such a way as to restrict the growth of the tree.

Extermination of the passenger pigeon

Birds need protection. Several species of American birds have already been completely destroyed by man, so that no living specimen

Am. Mus. Nat. Hist.

FIG. 187. A group of mounted specimens of the passenger pigeon. No birds of this species, which was distinctively American, remain alive.

can ever again be seen. The best-known case of this kind is that of the passenger pigeon. Within the memory of living men, it is said, passenger pigeons traveled in flocks that darkened the sun. With no protection of the law, they were recklessly slaughtered for the markets. The last specimen died in the Cincinnati Zoölogical Garden in 1914, where it had been kept for twenty-nine years.

Two enemies of birds

We can save the lives of very many birds by never allowing a nest to be robbed, by disposing of unnecessary

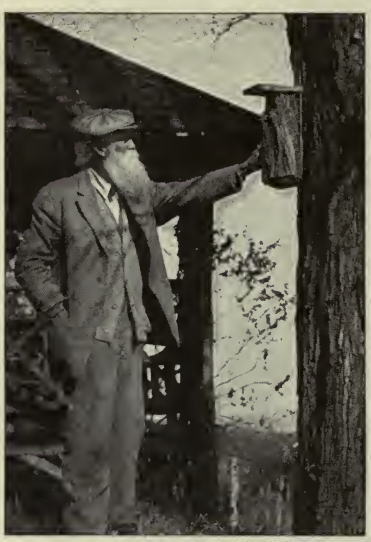
cats, and by properly feeding cats which are kept, so that they will not be tempted by hunger to prey upon birds. Snakes as well as cats often kill birds for food. On the other hand, snakes do a great deal of good by killing field mice and other small animals harmful to crops. (Most of the snakes of the United States are not only harmless but beneficial; but the rattlesnake, the copperhead, and the water moccasin should be killed because they are poisonous.)

Bird houses

Bird houses, if properly constructed, will be put to good use; but they will be especially appreciated by the kinds of birds that like to nest in hollow trees, because not so many trees of that kind are left standing as formerly. The Farmers' Bulletin referred to at the end of this chapter gives sketches and detailed drawings of many kinds of bird houses to suit the needs of different varieties.

W. T. Skilling

FIG. 188. In doing something to encourage birds, these pupils have found pleasure for themselves.



G. Clyde Fisher

FIG. 189. John Burroughs, friend of birds. He is America's best-known naturalist.

A house that one bird would like might not be entered by another (Fig. 188).

The best way to observe birds is to go where they like to stay and keep very quiet so that they will come near. Opera glasses will be found very useful in bird study. The writings of such men as Thoreau; Fabre, the great French student of insect life; and John Burroughs, are of the first importance as aids to nature study, and they make pleasant reading.

Experiments and Observations

1. Keep a calendar of birds of your locality, giving date when each is first seen and noting where it nests.
2. Watch the birds to see what food each eats.
3. From a concealed place, watch a nest of young birds and see how often the parent birds bring food to them.
4. Following the directions in Farmers' Bulletin 609, make bird houses suitable for some of the birds of your own neighborhood.
5. Find out what you can about John Burroughs, John James Audubon, and Henri Fabre.
6. What do you think is the meaning of the following poem,

called " Stupidity Street " ? It was written by Ralph Hodgson, an English poet.

I saw with open eyes
Singing birds sweet
Sold in the shops
For the people to eat,
Sold in the shops of
Stupidity Street.

I saw in vision
The worm in the wheat,
And in the shops nothing
For people to eat;
Nothing for sale in
Stupidity Street.

References

"Fifty Common Birds of Farm and Orchard." (Colored picture of each bird.) Farmers' Bulletin 513. Sold at fifteen cents by Superintendent of Documents, Government Printing Office, Washington, D. C.

"Bird Houses and How to Make Them." Farmers' Bulletin 609.

"Some Common Birds Useful to the Farmer." Farmers' Bulletin 630.

CHAPTER FIFTEEN

THE SMALLEST OF LIVING THINGS

The least of living things, I repeat, holds a more profound mystery than all our astronomy and our geology hold.

JOHN BURROUGHS

Our unseen friends and foes

IN the chapter on insects we noted that these little creatures outnumber by far all other members of the animal kingdom. But there are still other living things as much smaller and more numerous than insects as insects are smaller and more numerous than farm animals. They are in the air, in the water, and in the soil all about us, and as they carry out their life processes they are constantly doing us either good or harm. Among these tiny organisms are included all of the bacteria and many of the fungi.

Bacteria. The most minute of organisms are called " bacteria " (singular, " bacterium "). Every one should know something about the bacteria, for the invisible hosts of them add fertility to the soil, help to bring about decay of all organic matter, cause vinegar to ferment and milk to sour; and, on the other hand, they produce most of the diseases of mankind, such as tuberculosis, typhoid, diphtheria, and influenza. (The disease-producing bacteria are commonly called " germs.")

The smallest of living things

Bacteria are so small that if four hundred of some kinds of them were placed side by side, they would make a line only as long as a single page of this book is thick. None of them can be seen except with the aid of a powerful compound microscope, and many of them cannot be seen even with the best instruments. They

do not belong to the animal kingdom but to the vegetable kingdom. Each individual is a tiny plant, without roots, leaves, or stem (Fig. 190). Unlike ordinary plants, most bacteria are not able to prepare their supply of food from raw materials in soil and air. None of them are able to convert carbon from the air into plant food, though the nitrogen-fixing bacteria are able to use nitrogen from the air in manufacturing their supply of protein. Practically all of the bacteria must have for food some plant or animal matter.

The food of bacteria

FIG. 190. Bacteria of different shapes; some are spherical, some are rodlike, and some are spiral.

For the most part, bacteria increase in the simplest and speediest manner by constantly dividing (Fig. 191). A single bacterium, which may be in the shape of a ball or a rod, grows smaller and smaller at one point until the parts separate and each becomes a new individual. Bacteria may double their numbers every half hour if conditions are favorable. But supposing that divisions into two took place every hour, a single germ would in twenty-four hours increase to the enormous number of 16,777,216, as can very easily be figured.

How they increase in number

The increase in the number of bacteria cannot go on indefinitely, for it is limited by the supply of food within their reach, and also by substances that they themselves produce, which, in large enough quantities, are poisonous to them. An example of this is seen in the case of vinegar, which is produced by bacteria that work in the fermented juice of apples or other fruit. The bacteria

Why they do not multiply without limit

multiply very rapidly at first, producing great masses of what we call "mother of vinegar"; but when the acid has become strong it checks their increase. Their numbers are also reduced by microscopic animal germs called "animalcules." These are much larger than bacteria, and they use many of the bacteria for food. Furthermore, the white corpuscles in the blood of the larger animals destroy many harmful bacteria, and different varieties of bacteria destroy each other.

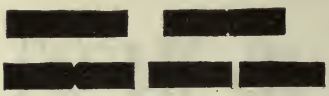


FIG. 191. Diagram showing how a bacterium multiplies by pinching in two.

The work of bacteria

Just as there are very many kinds of the ordinary plants upon the earth, so there are very many kinds of bacteria, drawing their food from different animal or vegetable sources and producing various results. Some kinds of bacteria aid in causing the decay of materials that they feed upon, and decay is a most necessary process in nature. Without it, dead vegetable and animal matter would not disappear and become a part of the soil, adding to the fertility of the land. The carbon removed from the air and built into plant substance would never be returned to the air in the form of carbon dioxid gas (Chapter Two), and soon plants would be unable to grow for want of it. We usually think of decay as an unpleasant process, but it is so only while it is going on. When decay is complete, there is nothing left of the substance decayed but some perfectly pure gases which mingle with the air, and a little mineral matter as odorless and as pure as any other part of the soil (Fig. 192).

Decay a necessary process

FIG. 192. The decay of dead vegetable and animal matter is caused by special kinds of bacteria. If decay takes place above ground, much material that would be of value to the soil escapes in the form of gases. If decay takes place in damp earth, or under a layer of leaves in a forest, humus is formed.

Preparation of plant food; humus

Decay carried to completion does not leave much plant food in the soil, but a partial decay in the earth of such material as stubble, roots, leaves, and manure produces humus, upon which plants are so dependent. Bacteria, then, aid in the formation of humus. But as the humus itself is not soluble in the moisture of the soil, it cannot be used by the plants as food before it has been changed by other kinds of bacteria, different from those that caused decay, into material that the roots can take up.

Soil bacteria; manure

Knowledge of the habits of these soil-enriching bacteria is very necessary to every one who cultivates a field, a garden, an orchard, or a flower bed. The first thing of importance to remember is that the bacteria must be able to find a supply of food in the soil, and that nothing answers the purpose so well as a plentiful

supply of barnyard manure plowed or spaded into the earth. The bacteria, in using this as food for themselves, convert it into food for the plants. Any mineral plant-food elements, like potassium and phosphorus, that are found in manure or other humus-forming materials, are set free by the bacteria for the use of plants. There are many bacteria in manure before it is put on the land, and one of the principal reasons for using it is to inoculate the soil with a new supply of bacteria.

Conditions that encourage the helpful bacteria in the soil

Moreover, as we saw in Chapter Four, some of the bacteria that live in the roots of legumes and others that live on refuse materials in the soil greatly benefit crops by increasing the supply of nitrogen available for plants. This is especially true in dry-farming regions, where bacteria penetrate the soil more deeply than they do in wetter regions. Moisture and air are both necessary for the life of these beneficial bacteria. For their best development, the soil should be damp enough to crumble readily when turned over with the spade, but it should not be so wet that it can be molded into shape in the hand. If the ground is kept soaked with water, the air cannot penetrate among the soil grains as it should and so be available to the bacteria. Airing the soil by frequent cultivation is one of the most important means of stimulating the activity of bacteria. Killing weeds is not the only purpose in hoeing a garden or plowing a field.

The bad effect of sour soil; the remedy

Sourness of the soil will kill most kinds of beneficial bacteria. A stiff soil that is poorly drained is the most liable to become sour, and the best remedy for sourness, aside from improving the drainage, is to treat the soil

with a good dressing of lime. The lime neutralizes or sweetens the acid much as soda sweetens sour milk in the making of biscuits. The lime, besides encouraging the action of bacteria, has several other important uses in the soil that have already been considered in Chapter Twelve.

Legumes

It is a good plan, every few years, to put in a crop of leguminous plants (page 45) such as clover or beans to rotate with the usual crops. The nitrogen-gathering bacteria that live in the nodules on the roots of the legumes will add to the store of plant-food material in the soil.

Bacteria of the dairy

Milk, being a suitable food for many kinds of bacteria, seldom contains fewer of them than several hundred thousand to a teaspoonful. These bacteria are usually perfectly harmless, most of them being of a variety that merely causes milk to sour. The reason milk does not sour when it is kept cold is that the bacteria that change the milk sugar into acid are not active at a low temperature. It is often noticed, however, that if it is a little too cool for milk to sour it develops a bad odor and taste. This is due to the fact that the bacteria that bring about decay can work at a lower temperature than those can that cause the souring; so milk should never be kept long unless at a very low temperature.

Bacteria that are our enemies

Most of the bacteria of which we have already spoken are harmless to us because they live only upon dead animal and vegetable matter; but there is a much smaller number that are capable of using living substance to feed upon and so of causing disease in animals and in plants. One kind when it develops in the lungs causes

consumption, another kind multiplying in the throat produces diphtheria, and still another variety whose natural home is in the digestive organs is the cause of typhoid fever. Disease germs are often carried on the feet of flies from filth upon which the flies have rested, to food upon the table, and it is for this reason principally that flies should be exterminated (page 183).

Flies as carriers of germs

Fungi and bacteria compared

Fungi. Fungi are plants that lack chlorophyll, and therefore, like most bacteria, they are dependent on animal or vegetable matter for food. As with bacteria also, there are beneficial and harmful forms of fungi. Some of them aid in the process of decay or cause mold. Others grow upon the bodies of insects such as chinch bugs, grasshoppers, and flies, causing the death of untold numbers of these pests. The yeast that is so important in bread-making is a fungus, and it is different varieties of fungi that give the distinctive flavors to various kinds of cheese. Though many fungi are so small that we need the aid of a microscope to study them, others, as the mushrooms and puffballs, grow to considerable size. We have seen that bacteria are tiny

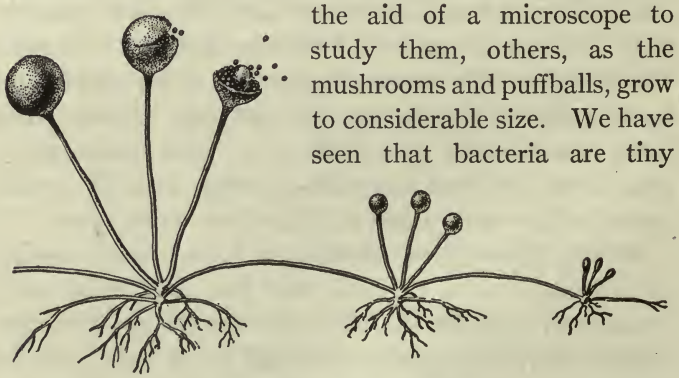


FIG. 193. Bread mold, showing the rootlike parts that absorb food from the material on which the mold grows, the filaments by which the mold spreads, and upright filaments on which spores have formed.

W. T. Skilling

FIG. 194. Smuts of corn and barley. The two heads of barley to the right have been blackened by smut.

specks; but fungi often form a network of webby material.

The life history of a fungus

The life histories of fungi are generally more complex than those of bacteria. Mold is a fungous plant, but unlike ordinary plants, it does not grow from a seed. It comes from a spore, which is much smaller than the smallest seed. Spores are very light and float about in the air. When one falls upon bread or cheese or anything that will furnish it with nourishment, it grows into a mold plant. First a white thread grows out from the spore; then this thread branches until it has formed a network of threads so fine that they are difficult to see without a microscope. This mold plant does not blossom, but clusters of spores form on the ends of the threads (Fig. 193). The spores are often blue or green,

giving the mold its peculiar color. Unlike bacteria, the fungi do not reproduce by means of division. However, some bacteria at times reproduce by means of spores.

Fungous diseases of plants; the damage they cause to crops

Most diseases of plants are caused by fungi, while most diseases of animals are caused by bacteria. Mildew, so often seen as a white powdery substance on the leaves of roses, is a fungus. The black smuts of corn, wheat, and other grains are fungi (Figs. 194, 195, and 196). Rust, which sometimes is so plentiful on grain that it rubs off as a brown powder, is also a fungus. It has been estimated that the yearly crops of the United States would be worth five hundred million dollars more than they are if it were not for the fungous diseases of plants. A large part of this loss could be avoided, for many of these diseases are preventable. The chemicals used to prevent the growth of fungus are called "fungicides," as sprays used to kill insects are called "insecticides."

Insecticides and fungicides

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FIG. 195. The effect of smut of oats on grains.

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FIG. 196. Two kinds of smut of oats; the effect on heads.

("Cide" is from the Latin, and, when attached to the end of a word, it means "killer.")

Insects and fungi are so different that what will kill one may not do the other any harm at all. However, to make one spraying do double duty, a fungicide and insecticide are often mixed, and both being applied at once, insects and fungi are destroyed together.

Bordeaux mixture

The oldest and most generally used of the fungicides is Bordeaux mixture. Its value was discovered by a vineyardist near Bordeaux, France, who sprayed his

W. T. Skilling

FIG. 197. Preparing Bordeaux mixture. This method of mixing the chemicals causes them to unite properly.

grapes with a mixture of bluestone and lime to discourage passers-by from stealing them. It was noticed that the grapes so sprayed yielded much better than those not sprayed. Bordeaux mixture is usually made with a strength of "five-five-fifty"; that is, five pounds of bluestone, five pounds of lime, and fifty gallons of water. To make one tenth this amount, dissolve half a pound of bluestone and half a pound of quicklime separately

W. T. Skilling

FIG. 198. Spraying a peach tree for curl leaf. This should be done before the buds open in spring.

in two buckets, each containing two and a half gallons of water (Fig. 197). (The bluestone will dissolve more readily if it is placed in a cloth bag that is suspended in the water. It should be dissolved in a wooden bucket.) Pour the two solutions together, both at once, into a third wooden vessel. Paris green may be added to the mixture to make it serve as an insecticide as well as a fungicide. The mixture should be used while fresh.

Lime sulfur

A spray that is very commonly coming to be used instead of Bordeaux mixture is lime sulfur. On account of the difficulty of making this in small quantities, it is usually purchased ready mixed. Lime sulfur is an insecticide as well as a fungicide. It is useful for killing scale insects.

Formalin and bichlorid of mercury

Two very important fungicides, which are used to disinfect seed to be planted, are formalin and bichlorid of mercury. Formalin, a liquid, is mixed with water at the rate of one pint to thirty gallons of water. Bichlorid of mercury is most conveniently used in the form of tablets as sold by druggists. These tablets differ in size, but enough of them should be dissolved in water to make a one-to-one-thousand solution. Directions on the bottle will explain how to do this. Bichlorid of mercury is extremely poisonous and should be handled only with the greatest care.

Various fungous diseases; peach blight and curl leaf

Peach blight is a fungous disease that kills the peach buds during winter, so that few leaves form; and "curl leaf" makes the leaves curl and drop off. For blight, spray with Bordeaux

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FIG. 199. Curl leaf of peach. If the tree from which this twig was broken had been sprayed with Bordeaux mixture, these leaves would be sound.

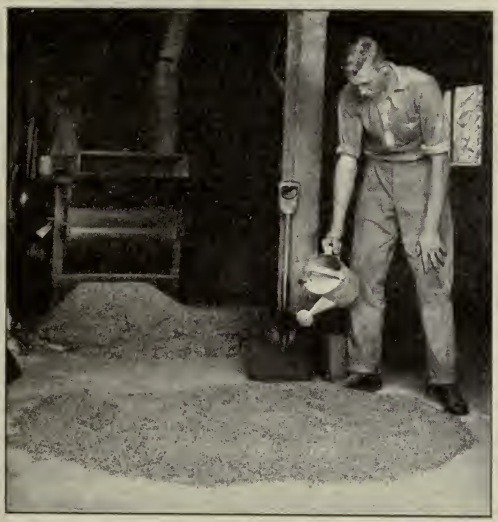

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FIG. 200. Disinfecting seed wheat for smut. The United States Department of Agriculture estimates that $35,000,000 worth of cereals could be saved annually by disinfecting seed.

mixture early in December; for curl leaf, spray just before the buds open in spring (Fig. 199).

Scab on fruit

Scab of apple and pear are caused by fungi. Spray with Bordeaux mixture about three times during early spring.

Potato blight and scab

There are two kinds of potato blight, "early" and "late," and these are caused by two different fungi. For both kinds of blight, spray once in ten days or two weeks with Bordeaux mixture. Potato scab is a fungous growth that roughens the skin of the potato. Soak seed potatoes for two hours in formalin, one pint to thirty gallons, or in bichlorid of mercury with a strength of one to one thousand.

Damping off

A fungus often attacks the stems of young seedlings in the nursery, making them rot off at the surface of the ground; such rotting is known as "damping off." The danger from this fungus is lessened by keeping the ground as dry on the surface as possible. Bordeaux mixture may be used as a spray.

Mildew

For mildew, a good remedy is flowers of sulfur. It should be dusted on the plants when the dew is on, so that it will stick. Repeat the dusting every ten days if necessary.

Smuts

There are different kinds of smut of wheat, oats, and barley, but most of them can be prevented by soaking the sack of seed grain for ten minutes in a barrel of formalin, one pint to thirty gallons of water, or by sprinkling the grain with formalin as shown in Figure 200. Smut of corn cannot be prevented by disinfecting the seed. Gather and burn all stalks that have smut on them, before the spores ripen and are scattered by the wind.

Experiments and Observations

1. Heat the same dish of milk to boiling every day for several weeks. The bacteria are killed and the milk remains good.

2. Find as many different samples as you can of mold, mildew, plant rust, and smut. Examine them with a hand lens or microscope.

3. Make and use Bordeaux mixture, following directions that have been given.

4. Disinfect seed potatoes with formalin.

References

"Cultivation of Mushrooms." Farmers' Bulletin 204.
"Some Facts about Malaria." Farmers' Bulletin 450.
"How to Prevent Typhoid Fever." Farmers' Bulletin 478.

CHAPTER SIXTEEN

THE HERD AND THE DAIRY

Then at the dairy's cool retreat,
The busy maids together meet;
The careful mistress sees
Some tend with skillful hand the churns,
While the thick cream to butter turns,
And some the curdling cheese.

JANE TAYLOR

The value of milk

"PROBABLY there is no other farm animal in which boys and girls are so vitally interested as the dairy cow. Their health, happiness, and often life itself depend upon intelligent care of this useful animal."[1] Scientists have shown that a plentiful supply of milk is necessary to the health and especially to the growth of children. They have also proved that milk from unhealthy cows or milk improperly handled may cause disease. In the past few years great improvements have been made both in the quality of dairy cattle and in the methods of caring for milk and milk products.

Danger

Origin of the principal dairy breeds

Breeds of cattle. All of our domestic cattle originated in Europe. The Holstein-Friesians (or Holsteins) came from Holland; Jerseys and Guernseys came from islands in the English Channel; and Ayrshires from Scotland. These are called dairy breeds to distinguish them from the beef breeds, which give very little milk but make a great deal more and better beef when dressed.

Beef breeds

The Herefords or "white-faced cattle," which were developed in Herefordshire, England, are a good example of a beef breed. All the beef breeds are

[1] Arthur D. Cromwell, *Agriculture and Life.*

squarely built as compared with the more slender dairy cattle. Their food is used in putting on flesh rather than in making milk. They give only about enough milk to support their calves. Dairy cows with their calves could not be allowed to run loose for months at a time on the Western ranges as beef cattle do without being milked, for their calves could not take all the milk, and the cows would suffer. Some dairy cows must be milked three times a day.

Differences in richness of milk

Dairy cows do not all give milk of the same quality. Jerseys give much richer milk than Holsteins. By "richness" is meant the amount of butter fat which the milk contains. By setting two bottles of milk side by side and allowing them to stand for one or two days, it is easy to see which has the more cream. This is only a rough test, however, for different samples of cream may have different amounts of milk mixed with them. Cream may contain anywhere from ten to sixty per cent of pure "butter fat." Tests have shown that the amount of butter fat in milk from different cows may vary from about three to six per cent; that is, some cows give milk twice as rich as others do.

Butter fat

Holstein-Friesians compared with Jerseys

The Holstein-Friesians unquestionably produce milk in larger quantities than do cattle of any other breed (Fig. 201). As compared with the Jerseys, the quantity of milk they give is almost double, but in richness it falls far short of Jersey milk. Average Jersey milk is about four and a half or five per cent butter fat, whereas that of a Holstein cow averages about three and a half per cent. As butter producers they rank fully as well as Jerseys, however, because the larger quantity of milk

Owen Duffy, Napa, Calif.

FIG. 201. A Holstein cow that gave 30,641 pounds of milk in a year, or an average of more than 10 gallons a day. She is registered under the name "Raphaella Johanna Aagie, Third." This cow holds the world's highest record for a strictly official test.

which they give is rather more than sufficient to make up for the lack of richness. The butter fat, being in finer globules, does not rise so rapidly as in Jersey milk, and so the milk does not appear as rich as it really is. (Exp. 1.)

Color and size

These Dutch cattle are very easily distinguished from all others by their black and white color. They are large, weighing fully one half more than the average Jersey and therefore requiring more feed. The name of the breed is derived from Friesland in Holland, their original home, and Holstein, a province in Germany, to which many of these cows had been taken before they were brought to America.

Name

Jerseys are well known to all because of their small

Gordon H. True, Univ. of Calif.

FIG. 202. A cow of the Dutch Belted breed, similar to the Holstein, but peculiarly marked.

Origin of the Jerseys

size and usually fawnlike color. This breed originated on the island of Jersey in the English Channel a few miles from the coast of France. For hundreds of years the people of this little island, which is but from four to seven miles wide and twelve miles long, have carefully bred these cattle with a view to increasing their butter-producing capacity. Jerseys give a fair quantity of milk, and it is exceptionally rich in butter fat. Some cows of this breed have a record of having produced as much as four or even five pounds of butter a day.

Their record

Guernseys

Guernsey cattle, like the Jerseys, come from one of the Channel Islands. They are similar to Jerseys but

Gordon H. True, Univ. of Calif.

FIG. 203. The champion Jersey cow of California. She produced 940.7 pounds of butter fat in one year.

are somewhat larger (Fig. 204). They did not attract much attention in this country until the time of the World's Fair in Chicago, when tests of various breeds showed the public that the Guernseys are fine butter producers. A peculiarity of the cream from the milk of Guernseys is that it is so yellow that no artificial coloring is necessary for the butter. The cows are less nervous and more gentle than Jerseys.

How these breeds were kept pure

In order to keep the Jersey and Guernsey breeds pure, the people of the Channel Islands have for more than a hundred years had laws forbidding the bringing in of other cattle except for immediate use as beef.

Ayrshires

The Ayrshires (Fig. 205) are Scottish cattle, and having been bred in the highlands where feed is difficult

W. H. Dupee, Santee, Calif.

FIG. 204. This prize-winning Guernsey (5 years old) produced 702 pounds of butter fat in one year.

to obtain, they are a very hardy breed. They are better able to get a living under adverse conditions than are any other dairy cattle kept in this country. In their native home their milk is much used in making cheese.

A breed that has been in America since colonial times

Shorthorn or Durham cattle originated in England and were brought here in colonial times. They have been more numerous and more useful in this country than any other breed. Some breeders have selected good milk producers and developed milk "strains," while others have chosen the heavier individuals of the breed and developed beef strains. Breeds of all animals are very likely after many years to become divided into several groups or strains, each different in some respects from other strains of the same breed.

Different "strains"

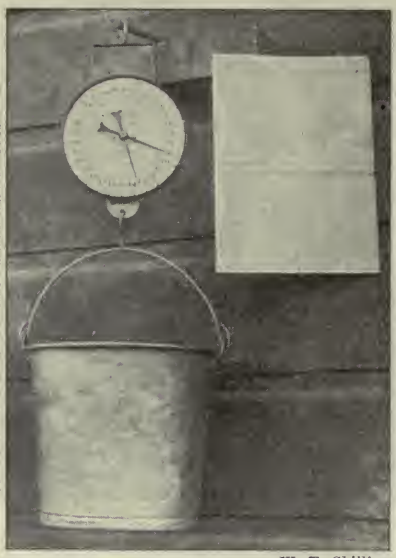
FIG. 205. An Ayrshire cow that produced 888 pounds of butter fat in a year, establishing the world's record for the breed. Registered name, "Lily of Willowmoor."

Colors of shorthorn cattle

It is a little difficult to distinguish shorthorn cattle by their color, for some are red, some white, and some red and white; but many of them are roans (covered with a mixture of red and white hairs), and these can easily be told, as cattle of no other breed have this color.

Building up a profitable dairy herd

Most farmers and dairymen nowadays realize the importance of keeping a good breed of cattle, but too few realize the equal importance of selecting the best individuals of any breed. It is useless to keep a cow that does not make a profit — a so-called "boarder." Good dairy qualities are inherited, and the farmer who breeds from high producers not only improves his own



W. T. Skilling

FIG. 206. Dairy scale and sheet for keeping a daily record of the milk produced by every cow in a herd. Such a record will enable the farmer to tell just how profitable it may be to keep each cow.

herd, but finds a very profitable market for any surplus stock he may have.

The rate of improvement possible

If a dairyman has scrub stock, it is very important that he breed up his herd by always keeping a pure-bred male. The first generation of calves will be at least one half pure; the second generation three fourths; the third, seven eighths; and the fifth, fifteen sixteenths pure. In this way even the wild Texas cattle, descendants of animals brought to the Southwest by the Spaniards, have gradually been transformed into the gentler and more valuable crossbred Shorthorns or Herefords.

How to select a good cow; the udder

The production of milk. In judging the value of a milk cow we naturally examine first the udder, where the milk is secreted. This should be large but not fleshy, and it should extend well forward and also well up behind.

Circulation

Another sign of a good milker is a large milk vein (Fig. 207). This vein runs like a rope along the under side of the cow's body, carrying blood from the udder

Morris & Sons, Woodland, Calif.

FIG. 207. The first cow to give more than 30,000 pounds of milk in a year. Her record for one year was 30,451 pounds. Notice the large veins on the udder, and the milk vein in front of the udder. Registered name, "Tilly Alcartra" (Holstein).

back to the heart. The larger it is the better the circulation of blood through the udder, and, therefore, the more milk can be secreted. A cow must be able to eat large quantities of food in order to make a large quantity of milk. Hence she must have a large stomach and a big, strong-looking mouth.

Digestion

Much can be told by the form of the cow. Her head and neck should be more delicately shaped than those of a beef cow. Her shoulders should be rather sharp and wedge shaped and her hips prominent, showing that her feed does not naturally go to producing flesh. Finally, she should be vigorous and healthy. This is indicated by her sleek coat, bright eyes, width and depth of the lower part of the chest region where the

The dairy build

heart and lungs are located, and by large, flaring nostrils, which are an excellent indication of lung capacity.

Telling the age of a cow

The ability to tell the age of a cow is of importance, for a young cow is worth much more than one ten or twelve years of age, whose usefulness is about at an end. During the first two years of a cow's life her horns grow rapidly and are smooth. Then, after a period of rest, a little more growth takes place, but at the point where growth had ceased before a ring is formed on the horn. Each year a ring is thus formed, and by adding two to the number of rings, the approximate age is found. In cattle that have no horns the age may be told by the teeth. Farmers' Bulletin 1066 shows pictures of the teeth of cattle at different ages.

Dehorning cattle

Cattle are less afraid of each other and eat more quietly together if they have no horns. For this reason their horns are often cut off, though this is a very painful operation. Keeping the horns of calves from growing is much easier than sawing them off later, and it is far more humane.

Preventing the growth of horns

Before the calf is eight days old each spot where a horn is to grow out should be dampened and then rubbed with the end of a stick of caustic soda or potash. Scabs will form and drop off and no horns will grow. Care must be taken to keep the hair dry so that the caustic soda will not spread and injure the calf's head. A ring of grease around each spot will help to keep the caustic from spreading.

Disease in cows

Tuberculosis is a disease that many cattle have, though they may show no outward signs of sickness. Milk from cows having tuberculosis is liable to cause disease in persons that drink it. Therefore the law in some

states requires that such milk be pasteurized (heated) before it is sold. Such milk if pasteurized is harmless, for the heat kills any dangerous germs that may be in it. *Pasteurization of milk*

There is a way of finding out whether or not a cow has tuberculosis. A liquid known as " tuberculin " is injected into the blood of the cow, and if it causes her to have fever for a few hours she has the disease. If she is free from the disease, no fever is caused by the injection. *The tuberculin test*

In many places milk is graded and priced according to quality. The highest grade is known as " certified milk." It often sells for nearly twice as much as milk of a lower grade. Other milk may be classed as " Grade A," " Grade B," etc. In order to have milk certified, some one representing the health board must visit the dairy frequently and certify to the board of health that the milk is produced in accordance with their requirements. *Grades of milk*

These requirements are generally like the following: (1) The cows must be tuberculin tested and found free from disease. (2) The milkers must be free from any contagious disease and stay away from any house where there is contagious disease. (3) Everything must be clean, — the cows, the clothes of the milkers, the milking place, and the utensils. (4) The milk must be quickly cooled after milking and be kept at a low temperature. (5) A bacterial count must show very few bacteria in the milk. (6) The milk must have a large percentage of butter fat. *Requirements for getting milk certified*

Whether one runs a dairy or keeps a single family cow, it ought to be his endeavor to produce milk of such

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FIG. 208. Cows in iron stanchions. The feed box shown at the rear is supported on rollers so that it can be pushed about easily.

How milk fit to be certified may be produced

quality that it could be classed as certified by the most particular health board. In order to accomplish this, the cows should be known to be free from disease, and they should be housed in clean, well-ventilated barns when not in the pasture (Fig. 208).

Keeping barn, cows, and milk free from dust

No cleaning should be done and no hay should be carried about the barn for half an hour before milking-time, for if dust is settling many thousands of bacteria will be carried by the dust particles into the milk. The cows should never be allowed to remain dirty, but should be cleaned with a brush or curry comb. The udder should be wiped with a damp cloth just before milking, so that particles of dust and hairs will not drop into the bucket. A hair may carry a great number of bacteria.

Cleanliness of the milker

The milker should be a person of cleanly habits, and his clothing should be clean. Many of the large dairies

require that white suits be worn to insure cleanliness. The milker should keep his hands dry — not moistened with milk or water, which might drop into the bucket. He should be free from any germs of infectious diseases, for such germs might get into the milk and be carried to many people. Out of one hundred and ninety-five epidemics of typhoid fever, the causes of which were sought for, it was found that one hundred and forty-eight probably came from dairies.

Avoiding danger from disease germs

Cleanliness of cans, buckets, bottles, and other containers is important, not only for the sake of health, but also because it keeps the milk from souring too soon. All vessels should be rinsed with cold or slightly warm water before the milk has dried on them, and they should

Keeping utensils clean

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FIG. 209. A sanitary milk house on a well-kept farm. The utensils have been turned upside down to drain.

then be washed in very hot water containing sal soda. A brush with a handle is much better than a cloth to rub them with, for washing with a cloth held in the hand does not permit the use of very hot water. Rinsing should be done in clean, hot water, and then the vessels should be left upside down to drain and dry without being wiped (Fig. 209), for it is difficult to keep a drying cloth sufficiently clean.

Cooling the milk

One of the most important operations to prevent the bacteria in milk from rapidly multiplying (Fig. 210) and souring the milk is to cool it promptly after it is drawn from the cow. In large dairies this is done by allowing the milk to run over a framework of iron pipes within which cold water or another cooling fluid circulates (Fig. 211). Such a cooler should be used only in a clean milk house where the air is free from dust. The most convenient and sanitary way to cool milk in a small dairy is to set the cans in cold water, stirring the milk occasionally.

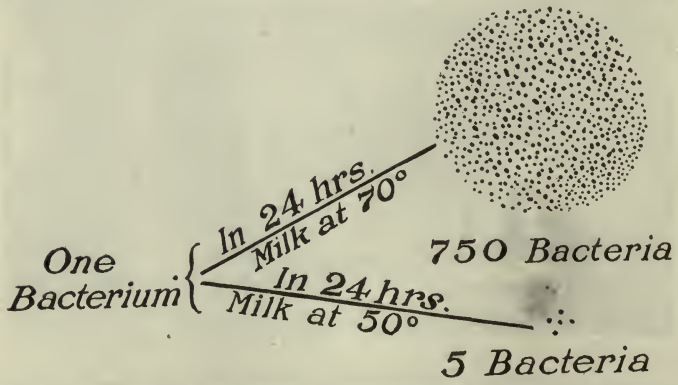

FIG. 210. The rates of increase of bacteria in milk at different temperatures.

When pasteurization is necessary; its effects

If the above directions are carried out, the milk is fit to be graded as "certified"; but if any precautions are omitted, it is then best to pasteurize the milk. This is done by heating it for twenty minutes at a temperature of one hundred and fifty degrees Fahrenheit, and then cooling it quickly. This process is sufficient to kill any bacteria that might cause disease, and if the temperature does not go above one hundred and fifty degrees the taste of the milk is not affected and it is quite as digestible as raw milk. Moreover, pasteurized milk will keep for a long time without souring, and therefore in cases where milk has to be transported for long distances pasteurization is almost a necessity. (Exp. 4.) Health boards recommend that all milk be pasteurized unless it is produced under very favorable conditions. Pasteurization does not remove dirt from unclean milk, but it destroys germs that might cause disease.

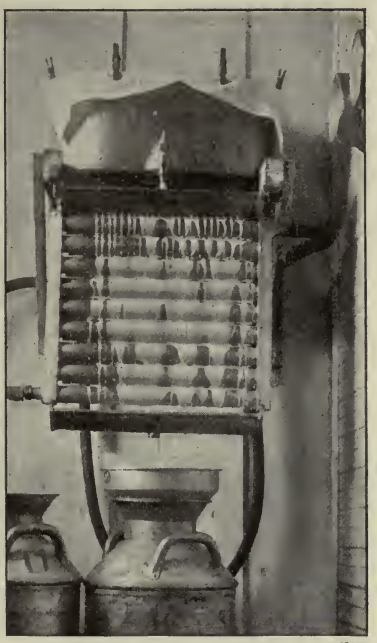

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FIG. 211. An effective milk-cooling device. The milk from the tank at the top is spread over the cold pipes. From the pipes it runs through the trough and into the can.

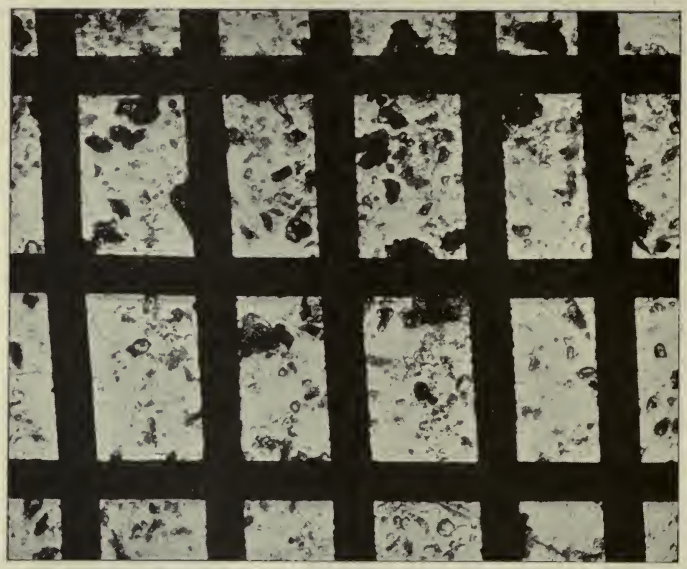

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FIG. 212. Section of a wire milk strainer, magnified, showing dirt from the udders of ill-kept cows.

Straining

A black sediment of dirt is sometimes found at the bottom of a pan after milk has stood in it for some hours (Fig. 212). This shows that the conditions under which the milking was done were not cleanly. If the cow is not clean, it is impossible to keep dirt from her hair from falling into the bucket, even if it is a milker's bucket with a small opening at the top (Fig. 213). This fine dust cannot be separated from the milk by straining; but the milk should always be poured through four thicknesses of cheesecloth or some equally good strainer to remove hairs and coarser particles. Cloth will serve better than a wire strainer (Fig. 214).

The clarifier

In large dairies a machine called a "clarifier" is used to free milk from impurities. In the clarifier milk is whirled so rapidly that foreign particles which are heavier than milk are driven to the outer edge of the machine, where they are drawn off. The force that drives the heavier particles out of the milk is the same force that throws the mud off the rim of a buggy wheel. It is called "centrifugal force. If the milk were allowed to stand long enough, the dirt particles would be separated by being drawn to the bottom by the force of gravity. But in the clarifier, centrifugal force separates them much more rapidly than gravity could. Milk treated in a clarifier is not easily digested and therefore should not be used to feed small children.

Testing milk; the Babcock method

As we already know, milk from some cows is nearly twice as rich as that from others; and since the greater part of the milk produced throughout the country is used for butter making, it is very necessary to be able to determine accurately the percentage of butter fat

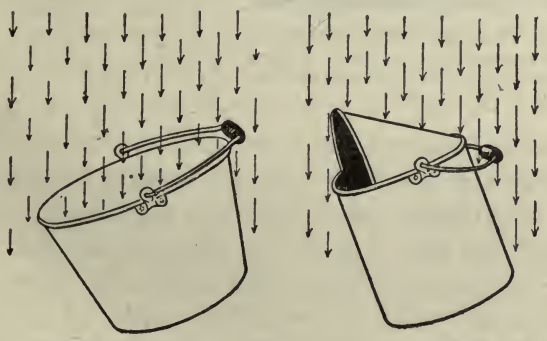

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FIG. 213. The open top permits all the dirt from above to fall into the bucket at the left. The closed top keeps most of the dirt out of the other bucket.

FIG. 214. More of the fine particles of dirt can be removed from milk by using a cloth strainer than by using a wire strainer.

Making the test

in the milk of each cow. To do this, Professor Babcock of the University of Wisconsin invented an instrument that shows how much butter fat any sample of milk contains (Fig. 215).

About a tablespoonful of milk is measured into one of the long-necked bottles shown in Figure 215, and a tablespoonful of strong sulfuric acid is added. The acid destroys the curdy part of the milk and so sets the butter fat free. (Butter fat consists of very small drops of oil that float all through the milk.) The bottle is now placed in one of the containers of the machine, and the crank is turned rapidly for five minutes. Centrifugal force causes the containers to swing outward till they are in a horizontal position. The heavy mixture of milk and acid is driven to the bottom of the bottle, which is now on the outside of the circle, and the oil drops, being light, come to the top. After this turning, warm water is poured into the bottle till

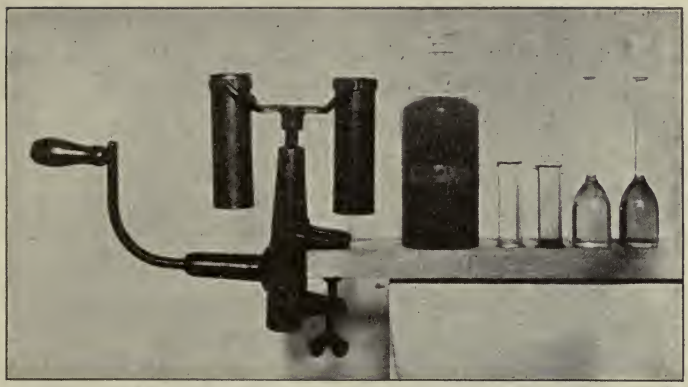

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FIG. 215. A small Babcock testing set: centrifugal machine, supply of sulfuric acid, beakers for measuring milk and acid, and bottles that give the readings.

it is filled just to the neck. The bottle is whirled for two minutes more, and a little more water is added so that the oil will float up in the neck of the bottle. The bottle is then whirled for one minute more. The length of the column of oil that now stands in the neck of the bottle indicates how much butter fat the milk contains (Fig. 216). There are marks on the neck for reading this amount in terms of percentage of butter fat. The whole operation can be completed in a little more then ten minutes.

Practical use of the test

This test is used by all creameries. A sample is taken from every can of milk that is brought in. The sample is tested, and the seller is paid so much for each pound of butter fat that the test shows the milk to contain. In the large machines used in creameries, twenty-four samples can be tested at once. As only about half an ounce of milk is taken from each can tested,

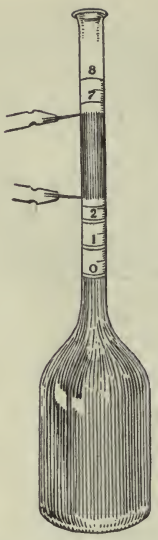

FIG. 216. A Babcock-tester bottle. The dividers are set to indicate the height of the column of butter fat. This height is laid off from "0" on the graduated scale. The upper pointer will then rest on the mark that indicates in figures the percentage of butter fat.

not much is wasted. Many farmers use small Babcock testers and thus are able to tell how much butter fat each cow produces. To determine how much butter can be made from a given amount of butter fat, it is customary to add one sixth to the weight of the butter fat, thus taking into account the water and salt that the butter will contain.

The cream separator

In 1879 a cream separator, which had been invented in Europe, was introduced in this country. Since then several different separators have been put on the market and are now widely used on farms as well as in creameries. These machines all use the principle of centrifugal force. The milk, being a little heavier than cream, is thrown to the outer part of the whirling separator, while the cream collects at the center. A tube leading from the center carries away the cream, and another tube leading from the outer part of the bowl lets the milk escape (Fig. 217).

Reasons for using separator

The advantages in using a separator are so great that many farmers milking only a few cows use small hand machines. Scarcely any of the cream is lost when a separator is used, while in skimming by hand a fourth of it is sometimes left in the milk. Also, when a sepa-

rator is employed the skim milk is ready to use while still fresh, and therefore it makes much better feed for calves than when it has stood until nearly or quite sour, waiting for the cream to rise.

De Laval Co.

FIG. 217. A hand separator.

Experiments and Observations

1. Observe and describe the various kinds of pure-bred cattle in your neighborhood. Find out how they compare for dairy purposes. Find out, also, how any crossbred cows you may see are influenced in appearance and value by the pure blood they possess.

2. Compare several cows, noticing which of them possesses the most marks of a good cow as described in this chapter.

3. Estimate the age of the cows you observe.

4. Whirl a small weight on the end of a string, and explain how the pull that is felt is utilized in the cream separator.

References

"The Dairy Herd." Farmers' Bulletin 55.
"Breeds of Dairy Cattle." Farmers' Bulletin 893.
"Breeds of Beef Cattle." Farmers' Bulletin 612.
"Production of Clean Milk." Farmers' Bulletin 602.
"Bacteria in Milk." Farmers' Bulletin 490.
"Farm Butter Making." Farmers' Bulletin 876.

CHAPTER SEVENTEEN

FARM ANIMALS AND THE PRINCIPLES OF FEEDING

The cattle are grazing,
Their heads never raising;
There are forty feeding like one!

WILLIAM WORDSWORTH

Why the hog is valuable

AN important matter that every farmer has to decide is whether to keep livestock and feed the crops he raises or to sell his crops and keep no stock. Cattle, sheep, hogs, and poultry require constant care. They cannot be left to themselves for a few days while the farmer takes a vacation, as a field crop sometimes may be. On the other hand, it often pays better to feed such crops as grain and hay, and sell the resulting product in the form of meat, milk, eggs, and wool, than to sell the crops directly; and keeping stock saves the expense of buying a great deal of fertilizer (page 42). The number of animals that the Illinois Experiment Station recommends for a farm of one hundred and sixty acres is eighty sheep, twenty-two cows, and twelve hogs.

A question in farm management

Keeping hogs. There are several reasons why the hog is one of the animals most commonly raised. It increases in weight more than other animals do in proportion to the amount of feed given it. A large part of its feed, if it is kept with cattle, is made up of what the cattle waste. It multiplies more rapidly than most animals do, as it frequently occurs that twice a year there are born litters of seven or eight pigs each.

Lard breeds

Breeds of hogs have been improved within recent years. The average hog of today is much larger than

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Fig. 218. Registered Hampshire hogs, part of a herd of forty belonging to this Oregon boy.

the average hog of fifty years ago, and its growth is more rapid. The five breeds most common in the United States are as follows: one red in color, the Duroc Jersey; one white, the Chester White; two black, the Poland China and the Berkshire; and one black with a white band around the body, the Hampshire. These are all known as "lard hogs." Two breeds less commonly raised are known as "bacon breeds." They are the Yorkshire and the Tamworth. The bacon breeds have longer legs and a longer body than the lard breeds. They look tall and thin in comparison with such hogs as the Poland China or the Duroc Jersey.

Bacon breeds

Corn being such an excellent hog feed, most of the hogs

Feed

FIG. 219. A family of Berkshires enjoying the sunshine. The white nose is characteristic of the breed. Note the model pen.

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FIG. 220. An automatic feeder for hogs. Grain comes down as fast as it is eaten.

in the United States are raised in the corn belt. But corn does not furnish enough mineral matter, and to supply this lack ashes should be kept in a feed rack. To the ashes are often added other minerals: air-slaked lime, salt, sulfur, and copperas. Several kinds of grain, to give variety, are better for feeding than any one grain alone.

The care of pigs

When young are expected, the mother should be separated from the other hogs, for they sometimes kill the little pigs. The pen in which the young are kept should have a guard rail within the wall and near the ground, so that the mother cannot crush the little pigs against

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FIG. 221. Inoculation prevents cholera in a hog (makes the hog immune) as vaccination prevents smallpox in a human being. Immunity against cholera lasts only a few weeks, and for this reason hogs should be inoculated whenever there is danger of the disease.

the wall if they happen to be behind her when she lies down.

Tuberculosis and cholera

Tuberculosis and cholera are the diseases most to be feared in hogs. Hogs (or cattle) that may be tubercular or otherwise diseased should be promptly sold to a meat-packing establishment. Parts of any carcass that the government meat inspectors find infected will be condemned as unfit for human food, and the seller will have to stand the loss, if he has sold subject to inspection. But by disposing of infected animals in that manner, a farmer will do much toward stamping out disease among men as well as among domestic animals. Epidemics of cholera among hogs have been the cause of great loss to farmers, but the danger from this source has been lessened by the inoculation of hogs, a

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FIG. 222. Milch goats in stalls. The white goats are of the Saanen breed.

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FIG. 223. Toggenburg does. Each of these has produced more than 4 quarts of milk a day.

treatment that makes them much less likely to contract cholera (Fig. 221).

Goats. In Europe the milch goat is known as "the poor man's cow"; and the goats that are kept there give enough milk to supply a small family — often as much as two quarts a day. We do not keep many goats, partly because the American breeds are not good milkers; but within recent years we have begun to import pure-bred milch goats, especially from Switzerland. Two valuable breeds from that country are the Saanen and the Toggenburg. Goats will eat much that other animals would not relish, but to thrive they must be well fed. Feeds used for cows are suitable for goats, but one cow will eat six or eight times the amount needed by one goat.

Imported goats

Feed

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FIG. 224. A Rambouillet ewe. The Rambouillets are a fine-wooled or "merino" breed. The heavy folds in the skin are desirable because they give a greater surface for the growth of wool. Merino sheep were developed in Spain. The Rambouillets are known also as "French merinos."

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FIG. 225. A Cotswold (long-wooled) ram. English or Scotch names — as Cotswold, Cheviot, and Southdown — indicate mutton, or general-purpose, breeds.

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FIG. 226. A dog-proof fenced lot, in which sheep may be placed at night.

Raising sheep on farms

Sheep. The great sheep ranches are in the West, for sheep require pasture land; but the Department of Agriculture is now recommending that farmers all over the country keep a few sheep (Figs. 224 and 225). One sheep to every two acres may be kept to advantage on many farms. The profit is partly from wool, but mainly from the half-grown lambs which are sold for mutton.

Housing and fencing

Sheep are so warmly clothed that they do not require expensive shelters in winter. All they need is protection from rain and wet snow. Dry snow does not hurt them. If they have plenty of pasture to graze over or if they have hay enough, they need little or no grain. They are very effective destroyers of weeds. Fences for sheep should be of woven wire and, if possible, should be high enough to keep out dogs. It is estimated that in this

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FIG. 227. A shepherd and his dog. In helping man to tend his herds the dog has, from the earliest times, been of great economic value.

country a hundred thousand sheep are each year killed by dogs.

Dogs. Although a few dogs acquire the bad habit of killing sheep, the fact that these outlaws exist should not spoil the reputation of dogs in general. The dog has been man's friend so long that there is no record of a time when it lived apart as a wild animal. It is known, however, that wolves, foxes, and jackals can be tamed if taken when young, and that many dogs in Alaska and other countries where wolves are abundant have some wolf blood.

The value of dogs

Both in town and country the right kind of dog, if properly trained, will make himself useful as a guard at night, as a pet, and as a destroyer of rats. The shepherd could not get along without his sheep dog (Fig. 227). Ten men could not make themselves as helpful to him in controlling the flock. In war, specially trained

dogs, carrying first-aid packages, have been used in finding the wounded. Alaskan dogs take the place of horses, which cannot so well endure the cold climate. Several breeds of dogs are especially useful in hunting. The hunter makes use of the greyhound's fleetness, the fox-hound's power of following a scent, and the pointer's skill in locating game.

Shelter

The hardy, long-haired dogs stand much more cold than can the small, short-haired breeds. Even the strongest dogs need comfortable shelter, but they should not be kept indoors. They are healthier if given a straw bed in a good kennel.

Exercise

Dogs are such active animals that they suffer in both body and temper if they are kept chained. If it is necessary to tie a dog, his chain may be made to slip

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FIG. 228. A rough-coated Scotch collie. There is a smooth-coated variety, not frequently seen. Collies are much used as sheep dogs, especially in Scotland.

FIG. 229. An Airedale terrier. Airedales make good watchdogs as well as pets, and they will kill rats. The breed originated at Airedale, in Yorkshire, England.

along a stretched wire so that he can run the length of the lot.

Feeding

In feeding dogs we should remember that they are by nature flesh-eating (carnivorous) animals. Their diet should contain some meat. The teeth of dogs resemble those of the wild carnivorous animals, being sharp and strong for biting and tearing, but not well adapted to chewing. Dogs swallow their food with very little chewing, and, consequently, it requires a long time for digestion. For this reason dogs should be fed only twice a day — a light meal in the morning and a more substantial one at night. Sweet foods should not be given them, and starchy foods should be fed sparingly. Irish potatoes are very bad for puppies. But the dog's diet should consist partly of vegetables.

Breeds

Among the two hundred breeds of dogs there are wider differences than among breeds of most other animals. Not only do dogs vary in size from the mastiff down to the toy spaniel, but they differ very greatly in disposition. The Scotch collie is a beautiful and intelligent animal (Fig. 228). The fox terrier is a small and active short-haired dog that is often kept as a pet. The largest of the terriers is the Airedale (Fig. 229). It is becoming popular as a watchdog.

Heavy and light breeds of horses

Horses. Of the heavy breeds of horses, the Clydesdale originated in Scotland, the Shire in England, the Percheron in France, and the Belgian in Belgium. Some of the light breeds for the saddle and carriage have been developed in this country and some in Europe, but these are all supposed to have descended, in part, at least, from the Arabian horse. Arabs are very fond of

Metropolitan Museum

FIG. 230. An Arabian horse. The best light breeds of horses in America and England have some Arabian blood. ("Arab Scout," a painting by Schreyer.)

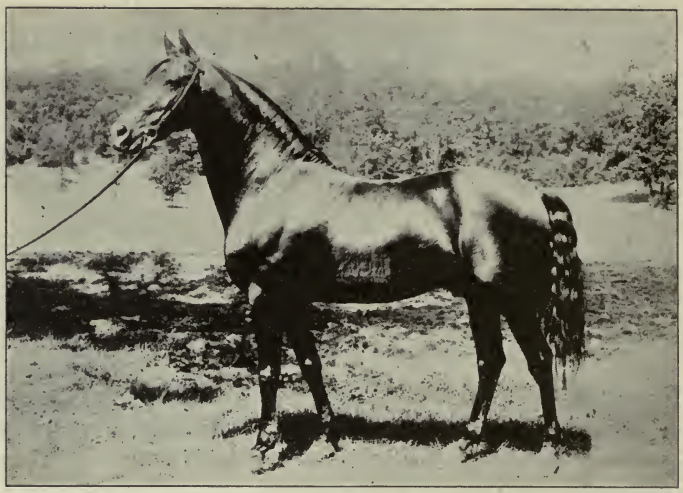

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FIG. 231. A Morgan stallion. Registered name, "General Gates." The breed, which is noted for its endurance and general serviceability, originated in Vermont.

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FIG. 232. Horses in action. Notice the gait. (Meissonier's " Friedland.")

their horses and they have taken pains to breed from individuals that excel in endurance and speed. The weight of the light breeds, such as the Arabian, the American saddle horse, and the Morgan, is about ten or twelve hundred pounds (Figs. 230 and 231). The heavy breeds weigh up to two thousand pounds or even more.

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FIG. 233. The mouth of a four-year-old horse. In each jaw there are four permanent teeth in front called "incisors." Three of these are visible in the picture. They are flanked by two milk teeth, one on each side, white and small. The picture shows one of these in either jaw. At five years the last milk teeth have been replaced by permanent teeth, and the horse is said to be "full-mouthed."

Gaits

The gait most suitable to a horse of heavy breed is a walk, but carriage and saddle horses may travel easily in any one of several gaits. In trotting, the right fore foot and the left hind foot are moved forward, then the other two. In pacing, both right feet move together and both left feet. The single-foot gait (or "rack" or "amble") is a combination between trotting and pacing. A single-footer makes an easy-riding saddle horse. The gallop is a movement of both fore feet at once and then both hind feet (Fig. 232).

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FIG. 234. At six years the cups, which appeared in all of the incisors at five years, have been worn away in the middle pairs.

Changes in a horse's teeth, according to age

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FIG. 235. The mouth of a 14-year-old horse. The teeth are long and slanting.

The age of a horse can be quite accurately told by its teeth, up to seven years (Figs. 233, 234, and 235). After that the age can only be estimated. Up to three years the animal has only small milk teeth in front. At three it gets two permanent front teeth in each jaw. At four it gets two more permanent front teeth in each jaw. At five the last of the milk teeth disappear and the horse has a full mouth of large teeth (six incisors above and six below), and these are all cupped. At six years the two middle pairs of teeth are worn down so that the cups do not show much. At seven another pair have lost their cups, and at eight all the teeth are worn smooth. After eight years the teeth become gradually longer and more slanting, but there are no marks by which the age can be told accurately. The molars are not taken into account in estimating the age of a horse.

Caring for horses

Horses are nervous animals, and a good driver will never yell at them. After becoming heated they should not be allowed to cool suddenly. Harness should fit well and be padded so as not to cause sores. Frequent grooming with brush and comb adds much to a horse's appearance and comfort. The front legs should be kept free from botflies' eggs, which will cause disease if they are licked off by the horse (Figs. 236 and 237).

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FIGS. 236 and 237. The eggs of botflies on the front leg of a horse; and a botfly, greatly enlarged.

The utility of rabbits in Europe

Rabbits. The wild rabbits of America have never been domesticated, but in Europe people have long kept rabbits as they do other domestic animals. The flesh is used as food, and the skins are made into fur garments, or the hair is removed from the skins and used in the making of men's felt hats.

Varieties of domesticated rabbits

Among the rabbits most commonly kept in this country are Belgian Hares, Flemish Giants, and New Zealand Reds. Belgian Hares weigh about eight pounds each when mature. They were imported from Belgium, where they are supposed to have originated. The New Zealand Reds, which are becoming very popular, are

said to have been taken originally from Scotland to New Zealand. They are of a reddish buff color and are a little larger than Belgian Hares. The Flemish Giants, the largest of all, should weigh fifteen pounds or more. All of these are kept chiefly for meat. The American Blue rabbit is appreciated for its beautiful fur, as is also the Himalaya. The Himalaya is a white rabbit about half as large as the Belgian Hare.

Two methods of housing

The commonest way of keeping rabbits in this country is to pen each one, except the young, in a separate house called a "hutch." The hutches may be made like the one shown in Figure 238, four feet long, two and a half feet from front to back, and eighteen inches or two feet high. If the floor is made of slats separated by narrow cracks, it is much easier to keep the hutch clean. Sometimes a number of rabbits are kept together in a pen to which shelters are joined; but unless the inclosure is very large, the ground cannot be kept clean, and diseases that are fatal to rabbits will develop.

Mating; the young

Rabbits should not be mated until they are about eight months old. A nest box twelve inches wide, twelve inches high, and eighteen inches deep should be placed in one corner of the hutch. A little soft straw or engine waste should be provided. With this the mother will make her nest, lining it with her own fur. The young should be weaned when they are about seven weeks old. The doe may be mated again when the young are two months old, and thus a new litter will come every three months.

Though rabbits make more work than chickens, having to be kept in separate hutches, they will eat

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FIG. 238. A New Zealand rabbit and hutch. Notice that there are cracks in the floor of the hutch, through which the light is shining.

Kinds and amount of feed

cheaper feed. Hay, vegetables, and almost any sort of green feed, including many kinds of weeds, make up a large part of their diet. (Cabbage and kale are to be avoided as not wholesome.) To do well, however, rabbits should be fed grain also. One successful breeder gives the following as a good daily diet for a rabbit: mash, three ounces (bran and beet pulp make a good mash); rolled grain, two and one half ounces; alfalfa hay, five ounces; green feed, ten ounces. A doe with

young needs very much more than these quantities. Twice a day is often enough to feed rabbits; but hay should be kept before them in a rack at all times. Grain can be given in the morning and green feed at night.

Substances of which the animal body is composed

Principles of feeding. We may get some idea of the kinds of feed that stock requires if we consider of what materials the body of an animal is made up. The bones contain large amounts of mineral matter, such as lime and phosphorus. The muscle — the lean meat — is made of a nitrogenous substance called "protein." (Exp. 1.) There is some fat in all animals; and every part of the body, but especially the blood, contains quantities of water. Evidently the food must contain something that will make bone, muscle, fat, and blood.

The body of an animal compared with an engine

It will help us in our study of the food needs of animals if we think of the body of an animal as being in a way like an engine, since the food that is digested, like fuel burned under a boiler, produces heat and energy. A hard-working animal requires more food, just as an engine drawing a heavier load than usual requires more fuel; and in winter more food is needed than in summer, in order to keep up the body temperature. It has been found that all foods give as much heat when digested as when burned — though more slowly. A food that will give a great deal of heat is a food that will give a great deal of energy to be used in doing work.

Mineral matter in feeds

The ordinary feed of animals furnishes most of the mineral matter needed. Oats, for example, is a good bone-making feed, containing three pounds of mineral matter in each hundred pounds. Corn contains half

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FIG. 239. The use of a feed rack prevents the waste of a great deal of hay.

as much mineral matter as oats, and wheat contains a little more than corn.

Supplying protein needs

If an animal is growing, its feed should contain an extra large amount of protein, as this is required for building up muscle. Also, if an animal is producing anything that it requires protein to make, as eggs or milk, the feed should be rich in protein. All kinds of grain and hay contain protein, though in very different amounts. Rice contains only seven pounds of protein in each hundred pounds of grain; corn, ten pounds; wheat, twelve pounds; bran, sixteen pounds; cotton seed, twenty pounds; soy beans, thirty-six pounds; timothy hay, six pounds; and alfalfa hay, fourteen pounds.

Muscle cannot be produced without food that con-

Oil and carbohydrates

tains protein, but any food may assist in forming fat. The chief fattening foods are oil and carbohydrates. (Sugar and starch are examples of carbohydrates.) Corn is used to fatten cattle because it contains large quantities of both oil and starch. There are five pounds of oil and seventy pounds of starch to each hundred pounds of corn. (Exp. 2.)

Oil as a food

Oil (or fat) may be considered as a sort of concentrated carbohydrate. It serves much the same purpose in food as sugar and starch; namely, to produce energy and animal heat. Oil is made of carbon and hydrogen, the elements that starch and sugar are made of; but it contains these elements in a different proportion, with the result that oil is more than twice as heating as either starch or sugar.

Feeding tests

The proper amount of feed. The agricultural experiment stations of the United States government have made tests to determine the values of different kinds of feed in different amounts, and they have kept careful records of the results. Thousands of feeding tests have been made in other countries as well, and a great deal has been learned from them.

The feed of horses and of cows

It has been shown by such tests that a horse weighing one thousand pounds needs about twenty pounds of feed a day, and that a cow of the same weight needs twenty-five pounds. Only the dry matter in the hay, after all moisture has been evaporated, is represented in these weights. The horse's stomach is smaller than that of the cow and it is differently constructed, so that the horse cannot eat so much. The horse, however, needs about as much nutriment as the cow; so its feed

should be more concentrated to furnish nourishment without too much bulk. Less hay and more grain is therefore required by the horse.

Balanced rations for cattle

A ration that contains protein, carbohydrates, and fats in correct proportion is spoken of as "balanced." Many tests have shown that the amounts of these three food materials that are needed to make a suitable daily ration for a thousand-pound cow when dry, and when giving thirty pounds (three and three fourths gallons) of milk, are as follows:

Kind of Feed	For Dry Cow	For Cow Giving Milk
Protein	.7 lb.	3.3 lb.
Carbohydrates	7.0 lb.	13.0 lb.
Fats	.1 lb.	.8 lb.

For the cow when she is giving milk, it will be noticed that the protein and fats are increased much more, in proportion, than is the carbohydrate.

Feeds that supply fat and protein

A dry cow will do very well on hay alone if it is of good quality, but if she is thin, she should also have a little grain, such as corn or oats. A cow giving milk needs more concentrated feed, and some of this should be of a kind that is rich in protein, such as bran and cotton-seed meal. With good alfalfa or clover hay the amount of concentrated feed required is less than if timothy hay is used. (Exp. 3.) An ox at heavy work requires about the same proportion of protein in its feed as does a cow giving milk. The cells in the muscles of a work animal are constantly being broken down and must be repaired with protein.

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FIG. 240. A silo. Notice the iron pipe for filling from blower, and the wooden chute for emptying.

Silage

To supply green feed to stock in winter many farmers build silos (Fig. 240) which they fill with green material, such as corn and alfalfa, the coarser matter being chopped fine or shredded. The wet silage is packed so tightly that most of the air is excluded. The material ferments, forming an acid that helps to preserve the silage much as sauerkraut is preserved. Cattle like silage, and they thrive better and yield more milk when they are fed on it than they do when kept on the usual dry materials.

Experiments and Observations

1. Wash the starch out of flour that is held in a cloth bag. Only a wad of tough gluten remains. This is the protein of wheat.

2. To extract oil from corn meal put a spoonful of meal into a cup and cover with gasoline. Cover the cup and let it stand overnight. Pour off the clear liquid into a clean dish, and set it in the sun for evaporation. The oil will be left. (*Keep gasoline away from fire!*)

3. Find out what the dairymen of your neighborhood feed their cows. What is the special purpose in the use of each of these feeds? What other feeds might be substituted for any of those now used?

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CHAPTER EIGHTEEN

POULTRY KEEPING

All climates agree with brave chanticleer. His health is ever good, his lungs are sound, his spirits never flag.

HENRY DAVID THOREAU

Backyard poultry

THE Department of Agriculture has estimated that seven hundred million dollars' worth of eggs and poultry are produced in the United States each year. Comparatively little of this immense product comes from large poultry farms. Most of it comes from the hundreds of thousands of farms and town lots where a few chickens or other fowls are kept in order that they may turn to profit food materials that otherwise would be wasted (Fig. 241).

Chickens as scavengers

Except in large cities, every family is better off for having a few chickens, provided they are kept out of gardens and at a suitable distance from any house.

Profit

They work every day in the year, helping to reduce the cost of living. Unlike most domestic animals, chickens are omnivorous; that is, they will eat all kinds of food. They are excellent scavengers, as they devour much matter that might decay and become disagreeable about a place. Like other birds, also, they do their share in preventing the increase of insect pests.

Keeping a single variety

Not many years ago most people who kept chickens were content with a mixed lot of various colors and sizes. Careful breeding of some particular variety was uncommon. But now, whoever pretends to give much attention to poultry keeping is sure to start with a desirable stock and to prevent mixture with other

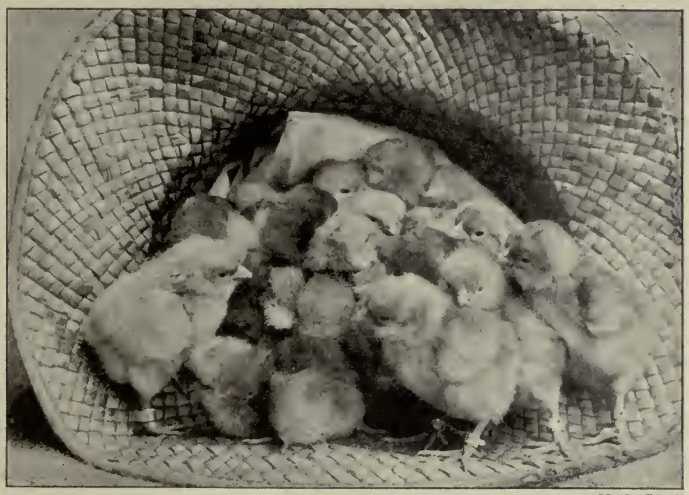

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FIG. 241. A start in poultry. The leg bands on the chicks will permit the owner to keep accurate records.

kinds. In this way the flock is kept uniform. Such a flock looks better and does better, and the uniform eggs generally sell at a little higher price than mixed eggs (Fig. 242 and Exp. 1).

The general-purpose type: American and English breeds

Breeds of chickens. The first breed to become popular in America was the Barred Plymouth Rock. At the suggestion of a friend, Joseph Spalding, a Connecticut poultry fancier, mated a common hawk-colored cock, a Dominique, with a Black Cochin hen. The chicks that resulted from the cross were found to resemble the Black Cochin mother in size, while most of them took their color from their Dominique father. The best chickens from this first brood were chosen to breed from. After several years of selective breeding, they were

How Plymouth Rocks originated

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FIG. 242. A standard-bred flock of single-comb White Leghorns. It costs no more to feed and care for good stock than for scrub stock, and the returns are much better.

exhibited at a fair held at Worcester, Massachusetts, in 1869, and they at once became popular.

Wyandottes; varieties

The popularity of Plymouth Rocks led experimenters to try to produce other improved breeds. The first notable result was the Wyandotte breed, which was originated in the state of New York by crossing several different breeds. The object of the breeders was to get a fowl that would mature earlier than the Plymouth Rock and be a better layer. The Silver-laced Wyandottes, the first variety produced, have three times secured the first prize at international egg-producing contests. There are now at least eight varieties of the Wyandottes, each distinguished according to color. In form and size they much resemble Plymouth Rocks, although they are somewhat smaller. They have "rose" combs (thick and low) instead of

"single" combs (thin and high) such as Plymouth Rocks have.

Rhode Island Reds

The little state of Rhode Island has for generations been a great poultry-producing region. Almost every farmer keeps several flocks of chickens scattered over his farm in separate colonies. Gradually, by mixing together any breeds that seemed to possess good qualities, the Rhode Island farmers secured a fowl of distinctive shape and color. The red color is so constant that it is noted in the name of the breed. The body is long, and it is large enough to make the breed a good meat variety. The Rhode Island Red is also a good layer.

Orpingtons

Plymouth Rocks, Wyandottes, and Rhode Island Reds are the three principal American breeds. A breed similar to these, though somewhat larger and having a

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FIG. 243. Rhode Island Reds, White Leghorns, and Plymouth Rocks, part of a school flock.

white skin, was originated in England at a place called Orpington. The first Orpington chickens were black, but other varieties of the breed have been developed, one of which is buff, one white, and one of a mixed color. The White Orpingtons are the best layers, probably because they possess some White Leghorn blood, this being a specially good laying breed (Fig. 243).

The egg type: Mediterranean chickens

The four breeds that have been considered are known as "general-purpose" chickens because they are both good layers and good meat producers. The Leghorns from Italy, the Minorcas from the island of that name, and other breeds from the Mediterranean region are known as "egg" breeds. The Leghorns, of which there are a number of color varieties, are very small. The Minorcas are larger, have long bodies, and stand very erect. The Black Minorca, especially, is a very handsome bird. But the Mediterranean chickens are not so good for meat as the general-purpose breeds, for they have larger skeletons in proportion to their flesh. All the Mediterranean chickens lay large, white eggs.

Leghorns and Minorcas

Characteristics of Leghorns

The Leghorn undoubtedly lays more eggs than any other breed in proportion to the amount of feed eaten. Leghorns are very active and require either a large range or plenty of straw to scratch in. They seldom become broody, and when they do sit they rarely stay on the eggs long enough to hatch them. Leghorns are quick-maturing chickens, the cockerels making excellent broilers at two months and the pullets sometimes beginning to lay at five months. They do not stand cold as well as the larger, loose-feathered breeds, and they are troublesome about flying. For these reasons some general-

purpose breed is often considered more desirable on the farm. But Leghorns are very generally kept on large poultry farms, the white and the brown varieties being most popular.

The meat type: Asiatic chickens

The principal breeds of the meat type of chicken are the Brahmas, Cochins, and Langshans, all of which have come to us from Asia. They are very large, and the thick coat of fluffy feathers extending down the legs makes them appear even larger than they are. The quantity of feathers helps to adapt them to cold climates.

Brahmas

Brahmas are the largest of all breeds, the males weighing twelve pounds and the females nine and a half pounds. They are thought to have originated in India. They were once quite popular in America, but now few of them are to be found. There are two color varieties, the light and the dark.

Cochins

Cochins of several colors, the Buff Cochin being most popular, are found to some extent in this country. They are more abundantly feathered than even the Brahmas, the Buff Cochin hen looking almost like a huge, fluffy ball of light-brown feathers. The Cochins originated in southeastern Asia. They were formerly called "Shanghais."

Langshans

The Langshans, nearly related to the Cochins, were originally brought from the Langshan district in northern China. The commonest variety is black. The Langshans carry both head and tail high and are fine-looking birds.

What each breed should weigh

According to standards of perfection adopted for the various breeds and used in judging fowls at poultry

shows, the following table gives the right weights for each:

Type	Breed	Cock	Hen
		pounds	*pounds*
General-purpose	Plymouth Rock	9½	7½
	Wyandotte	8½	6½
	Rhode Island Red	8½	6½
	Orpington	10	8
Egg	Leghorn	5½	4
	Minorca	9	7½
Meat	Brahma	12	9½
	Cochin	11	8½
	Langshan	9½	7½

How to raise good layers

Important as it is to have a good breed of chickens, it is equally important to have a good strain of that breed. In every breed some hens are better layers than others, and their special characteristics are inherited by chickens hatched from their eggs. If eggs from the best layers of each generation of chickens are selected for setting, a strain of good layers will soon be developed. It is important that the cockerels be hatched from eggs of good laying hens. There are many poultry breeders who believe that egg-laying ability is inherited more through the male than through the female.

The quality to breed for

With chickens, as with cattle, it is better to breed from the high producers than from those that have some special "show" color or other unimportant character. It is sometimes remarked that White Leghorns are even better layers than Brown Leghorns because breeding for color takes less attention with the white variety.

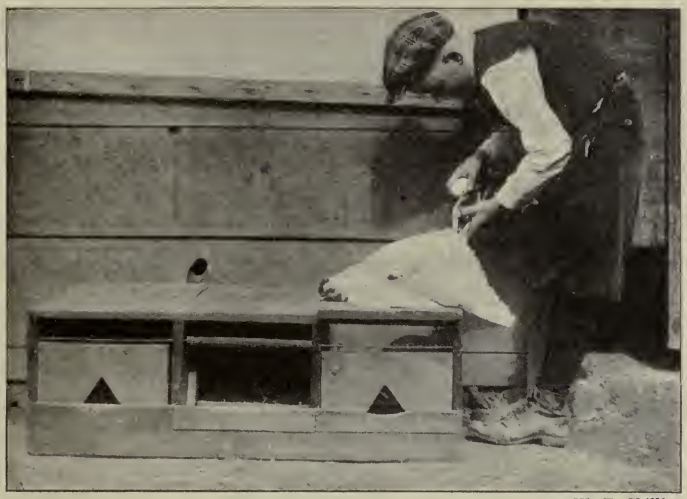

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FIG. 244. Trap nests. It is necessary to visit the nests several times a day, and to record the number on the leg band of each hen that lays.

How to determine which hens are good layers; color of legs

It has been proved that hens having faded white shanks are good layers. The eggs from a hen whose legs are still yellow after one laying season should not be saved to set. The coloring matter of the breeds having yellow legs seems to be used up in producing eggs. This theory is of no value in the case of breeds having naturally white legs, such as the Orpington.

Hoganizing

Another way to tell whether or not a hen is a good layer is to measure the space between the end of the breastbone and the pin bones, and also the space between the pin bones. The more fingers one can lay in these spaces, the better layer a hen is likely to be. Mr. Hogan of Petaluna, California, originated this test.

Trap nests

To find out with certainty which hens are good layers

and which are not, the thing to do is to employ trap nests, and to keep a record of the number of eggs that each hen lays (Fig. 244 and Exp. 2).

Turkeys

Other poultry. Distinct varieties of domesticated turkeys are found in various countries, but all of them are descended from the wild turkey, which was not known until America was discovered. The usual color in Spain

Breeds

is black, and in Holland it is white. In Rhode Island and Connecticut there has been developed a gray variety called the "Narragansett" turkey. The commonest variety is the Bronze turkey (Fig. 245), which is very little different from the original wild stock, some few of which are still found in the forests. Turkeys are hardy fowls when grown. The young, however,

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FIG. 245. A Bronze turkey mother. Benjamin Franklin was in favor of making the turkey our national bird because it is native only to America.

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FIG. 246. A white Muscovy drake.

The young

are delicate and difficult to raise, and they must be kept out of damp grass, as they easily chill to death.

Ducks

All breeds of ducks except one (the Muscovy) have been developed from the wild mallard in the Old World. Ducks eat much more than chickens, and as egg producers they are generally considered less profitable than hens. They are raised mainly for meat. The Rouen duck, from northern France, very closely resembles the mallard. The Aylesbury duck, the common English breed, is white. So, also, is the Pekin duck, originally from China, which is the most popular breed in America. The Indian Runner, a duck that stands almost erect, is the best layer of all. It is spoken of as the Leghorn of the duck family.

Various breeds

Muscovy ducks

At least one other breed of ducks is of interest to us — a breed distinct from all of those that sprang from the wild mallard stock. They are called "Muscovy"

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FIG. 247. A flock of Toulouse geese.

ducks, and they were brought from South America. (The reference in the name is to musk and not to a part of Russia.) They are the largest of all ducks, the adult drake weighing ten pounds; and they are very quick to mature. Muscovies are not so noisy as ordinary ducks. They are sometimes spoken of as "quackless" ducks, for their call resembles a peep rather than a quack. Five weeks are required to hatch the eggs of the Muscovy, the eggs of other ducks requiring but four weeks (Fig. 246).

Geese

The breeds of geese that are most popular in this country are the Emden and the Toulouse. The Emdens are the white geese that we ordinarily see. They were originally brought from Germany. The Toulouse geese are the common gray variety. They originated in southern France, but they were first brought to this country from England. No geese are very profitable as egg

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FIG. 248. Canada geese, the wild variety once common in North America. These are raised in domestication chiefly for use as decoys — an unworthy purpose, since our wild geese are already in danger of extinction.

producers. They are all kept chiefly for their flesh and feathers, or for ornament. The Canada goose, the common wild variety, is domesticated in some localities (Figs. 247 and 248).

Guinea fowls

Guinea fowls are native to Africa and Madagascar. Although the domestic varieties have been in captivity for centuries, they still retain their wild nature. They thrive only on the farm, where they have plenty of room to forage and where they can hide their nests and hatch their young in secret. Like wild birds, they will desert their nests if these have been disturbed. Being so wild and alert, they add to the safety of the poultry yard at night by setting up a loud clatter if any one intrudes. The common breeds are the gray (or pearl) guinea and the white guinea. The flesh of guinea fowls makes a good substitute for wild game, and their small, dark-

brown eggs, generally used for cooking, are of good flavor. Guinea hens are good layers.

Pigeons

The many different breeds of domestic pigeons are all believed to be descended from the wild rock doves of Europe and Asia. They are known to have been in domestication for at least three thousand years. Homing pigeons were formerly much used for carrying messages. A few pigeons are often kept as pets, and in larger numbers they are made a source of profit through the sale of squabs (young pigeons). The parent birds take turns in sitting upon the two eggs, and when the young are hatched they give them a partly digested food from their crops, called "pigeon milk." Pigeons free to fly find much of their own food and require little care, but when kept confined they should be fed several varieties of grain, and they should be supplied with green feed, shell, and rock salt.

The colony method and the intensive method of keeping poultry

Caring for poultry. When only a few dozen chickens are kept on a farm where they have an abundance of range to forage over, they require little care. But where several hundred or several thousand fowls are kept on a small area, they must be carefully handled. There are two methods of managing large numbers of fowls: one is to separate them into small flocks (colonies) and scatter them over the farm as far apart as possible, each colony having its own little house and range; the other is to keep them all in one house or in several houses close together (the "intensive" method), with little if any range. By the colony method a great deal of freedom is allowed the chickens, and they are more easily kept in a healthy condition. But the work is

Mo. State Poultry Exp. Sta.

FIG. 249. A model poultry house, the result of years of experimentation and study at the Missouri State Poultry Experiment Station.

much less in caring for one large flock than in caring for several small flocks.

Houses

Wherever possible, poultry houses are built facing the south, with a part of the front closed only with screen wire so as to give sun and air free access (Figs. 249 and 250, and Exp. 3). A cloth curtain is so arranged that it can be let down to close the front more securely in stormy weather. Poultrymen have learned that fowls, like people, are more vigorous and healthy if given plenty of fresh air and sunshine. In very cold climates a roosting closet is provided inside the chicken house, so that the fowls may be warmer at night. This closet is shut off only with a cloth door, so that plenty of air will enter.

Air and sunshine

Warmth

Doubling the floor space

A style of coop that will accommodate comfortably a larger number of chickens than would otherwise be possible on a small space is built with two floors connected

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FIG. 250. Mixing concrete for the floor of a school chicken house.

by a stairway. This doubles the area over which the chickens may move about. The lower floor is of earth that is kept soft and fine for the fowls to scratch in and dust themselves. The upper story is provided with roosts and nests, and troughs for feed and water; and the board floor is kept covered six or eight inches deep with cut straw. The straw keeps the place clean and gives the chickens something to scratch in for their feed, compelling them to exercise.

Roosts and nests

The roosts may be made of two-by-two-inch sticks with the corners rounded off a little. About ten inches under the roosts there should be placed a platform made of planed boards so that it may easily be cleaned. The nests are made in compartments about a foot square, the tops being covered to keep the nests clean. Partitions between nests are often omitted, so that several hens will not try to crowd into one nest. For a few

hens, small packing boxes, as sweet-corn cases, can be made to serve very well. Chickens will be more likely to use nests if they are somewhat hidden.

Why chickens need feeds that are rich in protein

The feed of chickens needs to be more concentrated than that of ordinary farm animals, because of their rapid growth, for which much protein (muscle-building food) is necessary, and because their eggs are rich in protein (Fig. 251). Protein, as we have learned (page 291), must be supplied in food, as an animal cannot turn other food materials into protein. If there is not sufficient protein in the hen's feed, she must wait until she accumulates enough of it, before laying an egg.

Meat, sour milk, oil meals, bran, and grains

The jungle-fowl ancestors of chickens (Fig. 252) were able to catch enough insects to make up their protein supply, and domestic chickens must be supplied with meat, or sour milk, or some special feed as a substitute for insects in their diet. There are several kinds of ground feed that contain large amounts of protein and oil. These are known as oil meals. They make good chicken feed. Examples of oil meals are soy-bean meal, linseed meal, and cotton-seed meal. Bran, also, contains a good deal of protein. The ordinary grains, such as wheat and corn, do not contain a large enough proportion of protein to supply the laying hen's needs (Fig. 253).

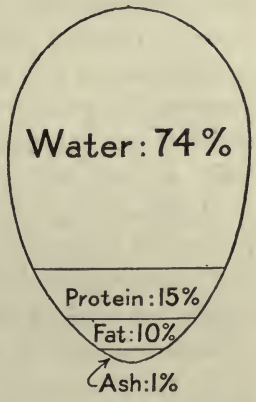

FIG. 251. What it takes to make an egg. Analysis by weight.

We often hear it said of hens

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FIG. 252. The jungle fowl of southeastern Asia, from which our domestic chickens are descended. Notice the resemblance to a gamecock.

"Too fat to lay"

that they are too fat to lay. Hens seldom become over-fat because they get too much feed — they can hardly get too much of the right kinds of feed — but because they get too much starchy feed, generally grain, which makes fat, and too little feed containing protein, such as meat, milk, or oil meal, which makes eggs.

The amount that a hen will eat

The amount of feed that a Leghorn hen should have in a year has been found to be about seventy-two pounds, not including green feed. About one half of this amount should be whole grain, the other half ground feed or

Proportions to be fed

"mash" (Figs. 254 and 255). The grain ration may be made up of a mixture of any two or three of the ordinary grains, as wheat, corn, oats, barley, or milo. If hens do not have plenty of room in which to range, their grain

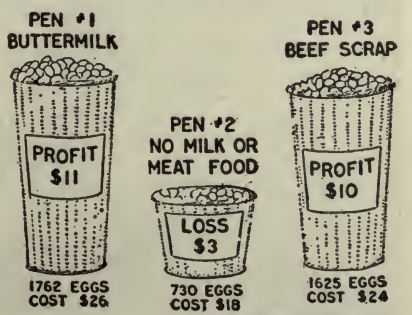
should be fed in six inches of straw. The mash should be about seventy-five per cent bran and ground grain, ten per cent oil meal, and fifteen per cent dried meat scrap. One pound of fine salt should be well stirred into two hundred pounds of mash. Large amounts of salt are poisonous — if a hen eats a lump of salt it will kill her. Cottonseed meal also is poisonous to chickens if it constitutes more than five per cent of the whole mash. Charcoal may be added at the rate of one pound to forty pounds of mash. The mash may be kept in a hopper before the chickens all the time. For convenience, and to keep the hens from eating too much, the mash should be fed dry (Fig. 256).

A sample ration for laying hens

The particular kinds of grain and mill feed to use will depend somewhat on prices in different parts of the country. One state experiment station recommends the following:

Grain ration. One tenth of a pound of whole grain a day, to each chicken. (The large breeds need a little more.)

Mash. All that the chickens will eat dry of the following mixture: bran, 50 lb.; ground grain, 25 lb.; oil meal, 10 lb.; meat meal or fish meal, 15 lb.; sifted salt, ½ lb.; charcoal, 2½ lb.



International Harvester Co.

FIG. 253. It pays to supply laying hens with feeds that contain a high percentage of protein. Each basket of eggs represents the production of a separate lot of 25 hens, during a period of 8 months, at the Ontario Agricultural College.

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FIG. 254. Breed as well as feed makes a difference in egg production. The average yearly production for each of 2000 hens entered in a contest was 151 eggs. The average yearly production of the common hen is 85 eggs. (Basket at left contains 151 eggs; that at right, 85.)

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FIG. 255. One year's feed for a hen, and her egg production. Based on prices in your neighborhood, what are the values of the "raw materials" and of the "finished product"?

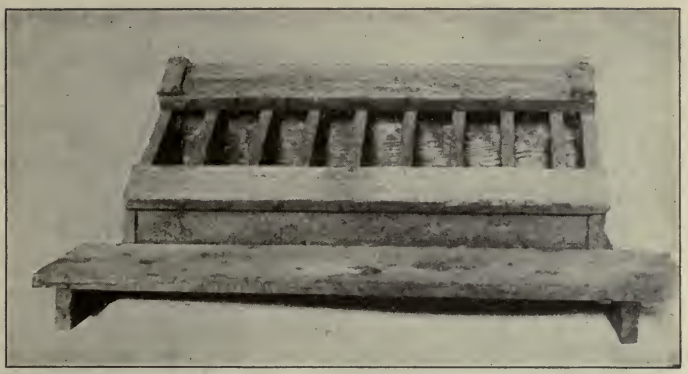

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FIG. 256. A box like this for feeding dry mash prevents waste.

Green feed, grit, lime, and water

In order to keep hens in health, they must have all the green feed they want daily. They should also be supplied with grit. It is generally considered that, having no teeth, fowls need to have grit in their gizzards to grind their feed. Ground oyster or clam shells are very commonly used for grit. The shells supply lime, which is so necessary in forming egg shells (Fig. 257). Pure water can most easily be furnished from a hydrant so arranged that the water will continually drop into the drinking receptacle. The water that may overflow should be carried away in a drain, to prevent mud. A drinking fountain like those shown in Figure 258 is used for chicks. They cannot drown in it.

Feeding chicks

Not until two days or even three days after the hatch is finished should the chicks have anything except water and sand. This is because nature supplies them with nourishment at this time, some of the yolk of the egg from which they were hatched being still in their digestive

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FIG. 257. A convenient box for supplying shell. Notice that the top opens on a hinge.

organs. Commercial chick feed is a very convenient and satisfactory feed for chicks until they are old enough to eat ordinary grain. If their feed is prepared at home, it may consist of rolled oats, hard-boiled eggs chopped up with the shells, stale bread or toast moistened, and cracked corn or other grain. Too much soft feed will injure their digestions. It is well to give them buttermilk to drink from the first day. When they are about a week old, they may be given a little dry mash each day. Chick mash should contain more bran and less of the more concentrated meals that are used in the mash for laying hens. If the chicks have all the milk they want, they do not need any meat meal in their mash.

Incubation

The body of a hen has a temperature of about 106 degrees, and when brooding her eggs she is able to keep them at about 103 degrees. By keeping eggs sufficiently warm with a slow smudge or charcoal fire, the Egyptians and the Chinese in very early times practiced artificial incubation.

Self-regulating incubators

Self-regulating incubators first came into use about 1875. They are devised, as nearly as possible, to repro-

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FIG. 258. A commercial drinking fountain for chicks, and a home-made one.

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FIG. 259. A feeding pen for little chickens. It is covered with coarse-meshed wire to keep other chickens out.

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FIG. 260. The two boys have operated this incubator with most satisfactory results.

duce the conditions of natural incubation. The burner which heats them is provided with an attachment that prevents the temperature from changing much. When the egg chamber gets too cool this self-regulator admits more heat, and when it gets too hot some of the heat is shut off.

Why moisture is necessary

To keep the eggs from drying out too much and weakening the chicks, the air within the incubator must be kept moist; so water is kept in a pan within the incubator, or the floor of the incubator house is sprinkled occasionally. Eggs for setting should never be washed, for water removes a natural coating which is necessary to keep them from drying out too fast.

Turning and cooling the eggs

The eggs are turned and cooled at fixed intervals, in imitation of the action of the hen. The mother hen's

instinct leads her to shuffle the eggs about frequently with her bill, and she comes off the nest each morning to get feed, often remaining away for twenty or thirty minutes until the eggs are nearly cold. Turning each egg is necessary to keep the chick from sticking to the shell. Eggs should be turned twice daily up to the eighteenth day. After that, each chick is so large that it cannot easily change its position in the shell, and so it is better not to turn the eggs any more.

Ventilation

It is necessary to allow fresh air to enter the incubator, for air is as essential to the life of the embryo chick within the shell as it is to the same chick a few weeks later. The porous shell allows the oxygen of the air to be absorbed into the blood of the chick. The hands should not be oily from handling the lamp when the eggs are turned, for oil on the egg shells would prevent air

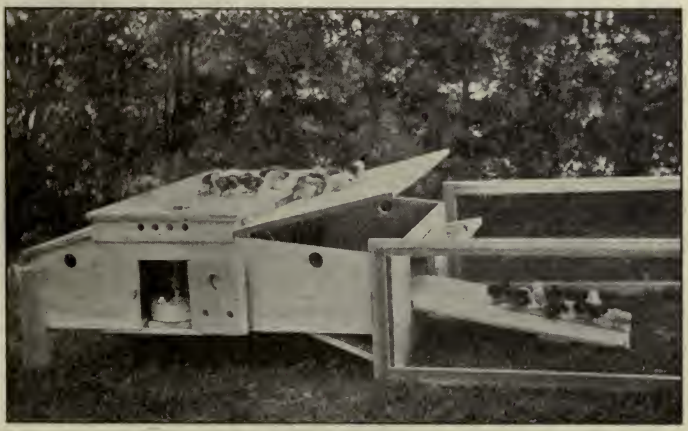
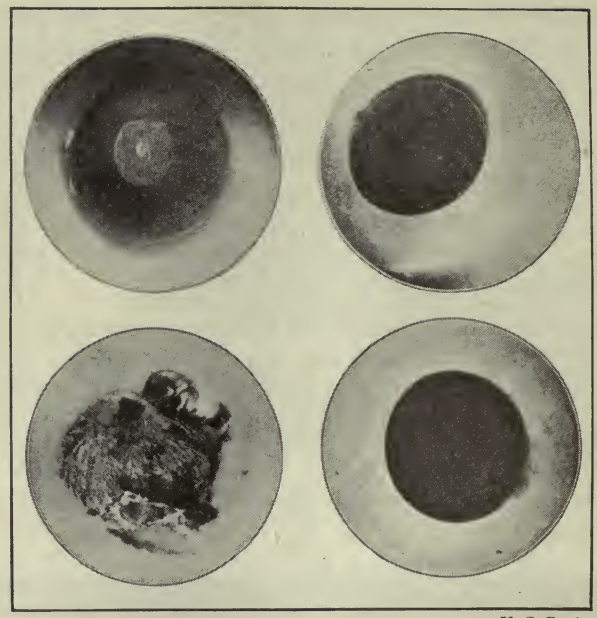


FIG. 261. A brooder made by pupils in the seventh and eighth grades at Platteville, Wisconsin. Young chicks need to be kept warm. The brooder temperature should be about 85° F.



U. S. D. A.

FIGS. 262 and 263. Figure 262 (above) shows a fertile and an infertile egg after both had been kept for 24 hours at the temperature required for incubation (about 103° F.). Figure 263 (below) shows a fertile and an infertile egg after both had been kept at this temperature for seven days.

from entering. A supply of air for the chick is stored at the large end of the egg.

Development of the embryo chick

Within less than a day after an egg has been set, the tiny germ has begun to grow (Figs. 262 and 263), and it is quite noticeable if the egg is broken and examined. In two days the heart, which has now begun to beat, is sending blood through a network of fine arteries and veins. In four days wings and legs begin to develop. The feathers begin to appear on

the eighth day. About two weeks are necessary for the hard beak and claws to develop. At the end of three weeks the now fully formed chick begins to peck with its hard beak against the inside of the shell, which finally gives way. Thus a ring is broken about a third of the way around the shell, when the chick, by pushing with its feet against the small end and with its head against the large end, bursts the shell all the way round and is free.

How the chick gets out of its shell

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FIG. 264. An egg tester. The cover for the lamp is of corrugated paper such as packing cartons are made of. At the bottom of the cover, to the right, are two holes to permit the entrance of air.

Testing eggs

Some of the changes during the three weeks of incubation can be seen through the shell by using an egg tester (Fig. 264 and Exp. 4). The tester may be simply a piece of cardboard with a hole in it, opposite which the egg may be held while looking through it toward a lamp. The process is sometimes called "candling." Eggs in an incubator are usually tested on the seventh day, for then the embryo in the fertile eggs has developed sufficiently to be easily seen. If an egg is infertile, it will be clear like a fresh egg. Such eggs are often taken out and used for food, though it is recommended that they be used as feed for young chicks. (Exp. 5.)

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FIG. 265. Preserving eggs in water glass. A quart of commercial water glass diluted with 9 quarts of water that has been boiled and then cooled is enough to preserve 15 dozen eggs. A covered glass or stoneware jar should be used.

Fertile and infertile eggs

Since infertile eggs are not entirely spoiled even by being under the hen or in an incubator for a week, we can see that they have good keeping qualities. This makes them more desirable than fertile eggs for marketing. A fertile egg begins to develop blood rings in about two days. Even the heat of warm summer weather will sometimes start the germ of a fertile egg to growing and make blood marks in the egg. Poultrymen usually keep the hens and the roosters separate when they want eggs for the market, so that the eggs will be infertile. Farmers' Bulletin No. 528 states that there is an annual loss of fifteen million dollars' worth of eggs due to blood

rings, all of which might be prevented by having the eggs infertile.

Preserving eggs

When eggs are plentiful and the price is low, it is a good thing to lay them away in crocks of water glass until they are scarce and high (Fig. 265). Water glass can be bought at a poultry supply store at about seventy-five cents a gallon, and one gallon will make ten gallons when diluted for use. (Exp. 6.) The shells of preserved eggs are apt to break in boiling, but this can be prevented by making a hole in each egg with a needle, before cooking.

The health of poultry

With chickens, as with people, hygiene is of more importance than medicine. Clean surroundings, suitable food, plenty of pure water, fresh air, exercise, protection from extremes of heat and cold, and the avoidance of contagious diseases — all of these make less the need for doctoring.

How to prevent vermin

The first condition necessary to keeping fowls comfortable and healthy is that they be

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FIG. 266. Dusting a hen with insect powder. The boy at the left rubs the powder in. It is especially important to protect sitting hens from lice.

free from lice and mites. Lice live and breed upon the bodies of the fowls, but mites remain hidden in crevices during the day, coming out only at night for their food. Plenty of fine dust or ashes should be where the chickens can wallow in it. The dust that they apply to their bodies protects them against lice. A lice powder, sold for the purpose, may be rubbed into the feathers, if it is needed. This attention is especially necessary for sitting hens (Fig. 266). A little lard smeared under the wings and on the heads of young chickens helps to keep them free from lice. For mites the best remedy is to paint the roosts or even the whole interior of the coop with carbolinium, a liquid which may be purchased at paint stores. This not only kills the mites, but prevents others from invading the coop for a long time. (Exp. 7.)

Removing causes of disease

Disease, whether in men or other animals, is in most cases the result of the work of germs; and the germs that cause a disease are likely to pass from one animal to another. To prevent a disease from getting a foothold or spreading, premises should be kept clean, for germs are abundant in filth. The drinking vessels of poultry should be scalded or cleaned frequently with an antiseptic to kill germs, and pure water should be provided. Contaminated water is a very common carrier of the germs of deadly diseases.

Contagious diseases

When a disease like cholera or roup appears in a flock, the sick fowls should at once be quarantined, or killed, and the premises should be freed of all infectious matter. Cholera is a disease of the digestive organs, and roup is similar to a severe cold in the head. Chickens are

to a considerable degree subject to colds and catarrh. These are germ diseases, that are especially likely to attack fowls that have to roost in cold, drafty places. People who keep chickens or other poultry under right conditions will not be troubled much by having disease in their flocks.

Experiments and Observations

1. Let pupils report the number of different breeds of chickens in the community. Let them bring in a specimen of each for study and comparison. Notice weight, color, legs, ear lobes, kind of comb, color of skin, and size and color of eggs.

2. Make a trap nest, following instructions in Farmers' Bulletin 682.

3. Draw a plan for a poultry house ten feet wide and twenty feet long. Estimate the cost of materials necessary to build it.

4. Make an egg tester as shown in Figure 264 and test a setting of eggs about the seventh day.

5. Set six eggs under a hen, one of the eggs being infertile. Each day open and examine one of the fertile eggs to see what progress has been made by the embryo. On the sixth day, examine the infertile egg.

6. Preserve a few eggs in water glass.

7. Under a magnifying glass, examine specimens of mites and poultry lice.

8. Observe a pigeon as it drinks. Other birds do not drink in the same way.

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